CAMBRIDGE BIOLOGICAL SERIES

General Editor:—Arthur E. Shipley, M.A., F.R.S.
FELLOW AND TUTOR OF CHRIST'S COLLEGE, CAMBRIDGE

TREES

VOLUME II

London: C. J. CLAY AND SONS,
CAMBRIDGE UNIVERSITY PRESS WAREHOUSE,
AVE MARIA LANE,

AND

H. K. LEWIS,
136, GOWER STREET, W.C.

Glasgow: 50, WELLINGTON STREET.
Leipzig: F. A. BROCKHAUS.
New York: THE MACMILLAN COMPANY.
Bombay and Calcutta: MACMILLAN AND Co., LTD.

Quercus Robur. The Oak (K).

TREES

A HANDBOOK OF FOREST-BOTANY FOR THE WOODLANDS AND THE LABORATORY

BY

H. MARSHALL WARD, Sc.D., F.R.S.,

Fellow of Sidney Sussex College, Hon. Fellow of Christ's College, and Professor of Botany in the University of Cambridge.

Author of *The Oak; Timber and some of its Diseases; Grasses; Disease in Plants; &c.*

VOLUME II. LEAVES.

WITH ILLUSTRATIONS

CAMBRIDGE:
at the University Press
1904

Cambridge:
PRINTED BY J. & C. F. CLAY,
AT THE UNIVERSITY PRESS.

PREFACE.

THE present volume, the second of the series, is devoted to a close study of the external features of the leaves of our woodland plants, especially from the point of view of the morphological characters which are found to be of systematic value. At the same time, I have incorporated such information regarding the anatomical and microscopic structure, and the functions of the typical leaf, as may enable a student familiar with elementary Botany, or even the beginner, to understand something of the marvellous powers displayed by this complex machine in breaking up the carbon-dioxide of the air and building it up into organic substances which serve as the principal food of the plant organism.

The leaf is the most plastic of all the organs of the plant, and it is by no means sufficient for the Forest student to know the mere shapes of ordinary leaves: he ought to be familiar with the principal varieties, and especially with the metamorphoses which leaves undergo, and it is hardly too much to say that he who really understands the conformation and adaptations of the leaf, holds the key to the morphology of the higher plants. It is for this reason that I have entered into some matters which may at first sight appear foreign to the purpose of the work as a whole.

In spite of expressed opinions to the contrary, I am convinced that much valuable exercise in observational and descriptive science can be obtained by learning to draw and properly describe the outline, margin, base and apex, and other peculiarities of leaves; and it is after considerable experience and mature reflection that I earnestly commend the advice in this connection I have ventured to offer on p. 28.

Some technical terms are indispensable; but so they are in carpentry, in a game of cricket, or in diplomacy! It is absurd to complain that the study of nature should demand technical terms to shorten and give point to description. It is only when such terms are multiplied unnecessarily and pedantically that the student has legitimate grounds for complaint: exact and new ideas must have definite terms for adequate expression.

As regards the illustrations, they are to a large extent due to Miss Dawson, to each of whose drawings the letter (D) is appended. The beautiful prints of leaf-venation are taken from Ettingshausen, denoted by (Ett). Other illustrations are original, or their sources are acknowledged as in Vol. I.

I must record my thanks to Prof. I. Bayley Balfour for specimens of Arctic and Alpine willows grown in the Edinburgh Botanic Gardens; to Mr F. F. Blackman for revising the proofs of Chapters IX—XII; and to my wife and son for preparing the glossary and index.

H. M. W.

CAMBRIDGE, *October* 1904.

CONTENTS.

PART I. GENERAL.

PART II. SPECIAL.

Classification of Trees and Shrubs according to the Characters of the Leaves.

PART I.

GENERAL.

CHAPTER I.

THE LEAF.

The typical foliage-leaf—Position and insertion—Nodes and internodes—Phyllotaxy—Angular divergence—Alternate and opposite leaves &c.—Displacements—Leaf-mosaic—The leaf as "a trap to catch a sunbeam"—Examples of leaf-insertion.

HOWEVER difficult it may be to define a leaf so as to exclude all things which are not morphologically leaves and to retain all which are, it may be safely assumed that the reader knows some common examples of foliage-leaves, and it will be well to confine our remarks at first to these only.

The ordinary typical foliage-leaf, then, is a flattened green expansion of tissues so displayed as to expose as large an area as possible to the light and air. These tissues are continuous with those of the stem, and present the most various modifications in respect of position, shape, size, texture, and other peculiarities which render foliage so different.

As regards position, the rule is that the leaf springs direct from the shoot or from one of its branches, and it is by the presence of leaves that we recognise shoots. The spot where the leaf begins to leave the stem is termed its *insertion*. The leaf-insertions may be close together,

and the leaves therefore crowded into a rosette, as in the Dandelion, Plantain, Strawberry, many Grasses and Ferns, &c., where the main stem is so short that the tuft of leaves seems to spring from the root in the ground—whence such leaves are termed *radical*; or in the Palms, Screw Pines, *Agave*, *Yucca*, Larches, Cedars, *Daphne Laureola*, and many others where the rosette or tuft of leaves is elevated on a stem or borne on branches.

In a still larger number of common plants, however, the leaf-insertions are separated by more or less evidently elongated portions of the stem, termed *internodes*, in contradistinction to the *nodes* or parts of the stem bearing the leaf-insertions. Examples showing evident internodes are afforded by most of our ordinary trees, such as the Elm, Beech, Ash, and shrubs such as the Lilac, Rose, &c.

The difference between the two classes of cases obviously depends on the relative growth in length of these internodes; for every gradation can be found between the *scattered* and distant leaves of the Passion-flower, *Aristolochia*, Vine, &c., which, like most climbers, have long internodes, and the rosulate or closely crowded leaves of the Spurge Laurel, Primrose, Cypress, Larch, Cedar, &c., where the internodes remain so short as to be practically obsolete.

In addition to their distance apart, moreover, the arrangement of leaves on the shoot (*Phyllotaxy*) is governed by the relations of the leaf-insertions to the stem in another way.

The leaves of the Ivy, Elm, Beech, Bramble, Fig, and Vine, for instance, are inserted singly, and in such a way that if a line is drawn from the insertion of any particular leaf so as to join the insertions of all those leaves situated higher up or lower down on the same shoot, the course traced will be of the nature of a spiral; this spiral insertion

of scattered leaves is so common and striking that much harmless ingenuity has been expended in reducing the different cases to statistics, while enthusiasts have gone further and tried to enunciate generalisations to which the name of laws has been given; somewhat too rashly, since the principles underlying the position of the leaves are much more fundamental than these so-called "laws of phyllotaxy" admit, and have to do with the space-relations and pressures in the bud, and the need for exposing the leaves in the best manner to light and air.

As mere facts of organography, however, a few of the commoner cases are useful.

Thus, if we join the insertions of the successive leaves of the lateral branches of the Lime, Elm, Beech, and many other plants, we find that in passing as above described from a given leaf to the one vertically above (or below) it, our line describes a spiral which goes *once* round the axis, and touches *two* leaf-insertions on the way, in addition to the one started from. In other words, the leaf vertically above or below the chosen one is the next but one, and the fact can be shortly expressed by the conventional formula $\frac{1}{2}$.

This kind of phyllotaxy is termed *distichous*, because the leaves can evidently be regarded as inserted in two vertical rows, one on each of two alternate sides of the stem.

If we had chosen one of the Cyperaceæ (Sedges) or the Alder, Birch, and some other plants, the spiral line drawn from any leaf to the one vertically above it would again pass *once* round the axis, but go through *three* leaf-insertions on the way, a fact expressed by the formula $\frac{1}{3}$, and the phyllotaxy is termed *tristichous*, the term *orthostichy* being employed to denote the vertical series, or rank, of leaves. With most branches of the Oaks, Willows,

Pear, Apple, Currant, *Ficus religiosa*, and very many other dicotyledonous plants, the phyllotaxy is expressed by $\frac{2}{5}$; the upper number denoting that our line passes spirally *twice* round the stem, and encounters *five* insertions before again coming to the leaf vertically above our starting point.

In the same way we arrive at the fact that the phyllotaxy of the Radish, the Cabbage, Flax, Holly, Aconite, and Plantain, with some others, is *octostichous*, $\frac{3}{8}$, and higher numbers such as $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, &c., are to be met with occasionally. See also Vol. I. p. 32.

For certain purposes these facts are sometimes expressed in diagrammatic form by projecting the above spirals on a plane, and marking all the leaf-insertions on the line: the fraction of a circle described in passing from any one insertion to the next is then spoken of as the *angular divergence* of the leaves.

In all these cases, and in those that follow, however, it must not be overlooked that many plants exhibit more than one kind of phyllotaxy, according as we select vertical or horizontal branches, and it is particularly common to find the phyllotaxy of the young seedling or of the basal part of a shoot quite different from that of the older plant or its parts; this is still more emphatically the case when we take also into account the leaves which have become adapted to special purposes.

At present, however, we are concerned only with the ordinary typical foliage-leaves. The various cases so far considered may all be regarded as coming under one general heading, and their phyllotaxy may then be termed *alternate*, or *scattered*: strictly speaking the former of these two terms refers to the *distichous* arrangement ($\frac{1}{2}$), but it is so commonly employed for all the above cases, that it seems unnecessary to limit it further.

In marked contrast to the above are the cases of *opposite* leaves, where we find two opposed leaf-insertions at each node of the axis. Common examples are met with in the Lilac, Elder, Honeysuckles and other members of the natural order (Caprifoliaceæ) to which these latter plants belong; also in the Maples, Horse-chestnut, Ash, *Cupressus* and *Thuja*, and numerous others, in some cases including whole natural orders.

In the vast majority of such cases, including all those quoted, the pairs of opposite leaves are so arranged that the longitudinal axis of each opposite pair is at right angles to that of each pair above and below, and this kind of phyllotaxy is universally known as *decussate*. We may here again also speak of the vertical rows of insertions as *orthostichies*, and then we have four such orthostichies in decussate phyllotaxy. There are very few cases among foliage-leaves where the opposite insertions are superposed on erect stems, e.g. some Euphorbias. *Loranthus europæus* and *Potamogeton densus* may possibly furnish exceptional cases, but in the latter the branches are floating and not erect, a fact in obvious relation to the need for the plant to expose its leaves to the light.

It is also clearly possible to regard opposite leaves as only a particular case of *whorled leaves*, that is where several leaf-insertions are situated at the same node or level of the axis; in practice, however, it is usual to limit the term whorled to cases where at least three insertions (e.g. Juniper) are at the same level on the axis.

Examples of whorled (or *verticillate*) phyllotaxy are the following. The Oleander, *Elodea canadensis*, and Junipers, have each usually three leaves in the whorl; *Lysimachia quadrifolia*, *Paris quadrifolia*, *Myriophyllum spicatum*, Heather, &c., have usually four. In the various

species of *Equisetum*, *Casuarina*, *Hippuris* and others, the whorls have numerous leaves.

The reader may compare the above with the statements concerning the arrangement of buds in Vol. I. Chap. IV.

It must be observed that phyllotaxy is only a particular case of the arrangement of lateral members, and that we have to regard it as subject to more general laws than need be referred to here. It has already been mentioned that the phyllotaxy may differ in different parts of the same plant, and even on the same branch; examples occur in *Fritillaria imperialis*, Oaks, Chestnuts, and several species of *Aloë* and *Monstera*, where the angle of divergence of the spirally arranged leaves changes as we pass up the stem; and it is by no means uncommon to find opposite leaves on the same branch with alternate ones, e.g. *Symphoricarpos*, *Salix purpurea*, *Rhamnus*, *Atriplex*, and occasionally the Ash and some others.

Still more difficult cases are those where the real phyllotaxy is obscured by crowding and displacements of various kinds, or by the interposition of organs which are not true leaves though they look like them. Examples of the first kind are the *fascicled* leaves on the dwarf shoots of many conifers, e.g. the Larch and Cedars, and on *Berberis vulgaris*; the displaced leaves of many Solanaceæ, such as the Bittersweet; the false whorls of some Lilies, &c., usually attributed to the suppression—i.e. the non-development—of one or more internodes. Examples of the second kind occur in the Bed-straws where stipules assume the aspect of leaves, and have no buds in their axils.

These cases have also to be distinguished from others where displacements are brought about by subsequent twistings or torsions of the stem. Such torsions are very

frequent, as in Screw Pines, and are probably often concerned in causing apparent alterations of phyllotaxy, e.g. in Aloes, *Dracæna*, some *Aroideæ*, &c.

We shall have occasion to discuss these matters from a more general point of view later on.

Meanwhile the student must be on his guard against confounding phyllotaxy, and the displacements referred to above, with the position of the leaf-surfaces themselves. Phyllotaxy is, strictly speaking, concerned with the positions of the *leaf-insertions*; but several causes may co-operate in bringing about curvatures of various kinds which place the *leaf-surfaces* in directions not at all obviously related to the phyllotaxy.

This subject of the arrangement of leaf-surfaces has come to be referred to in text-books under the head of *leaf-mosaic*. If we look down vertically from above at a freely growing erect foliage branch of the Sycamore, or the Norway Maple, for instance, it will be seen that the leaf-blades are so arranged that they catch the incident solar rays over their whole upper surfaces, and still do not seriously obstruct the access of such rays to leaves lower down : this is brought about partly by the decussate phyllotaxy, and partly by the larger size and longer stalks of the lower leaves which carry the blades of the latter well to the periphery of the area on which we can project the foliage (Fig. 1).

If we compare with this vertical branch a horizontal one of the same tree, the examination shows that a similar object—the advantageous display of as much of each leaf-surface as possible—is brought about by the twisting of the leaf-stalks, so as to bring those which would approach the vertical if they grew out from the leaf-insertions in the ordinary direction, more into a horizontal plane (Fig. 2).

These alterations in the position of the completed leaves, so as to expose as large a surface as possible in the best manner to the air and to the rays of solar light, go a long way towards explaining the peculiarities of foliage.

Here are a few examples. On the horizontal lateral

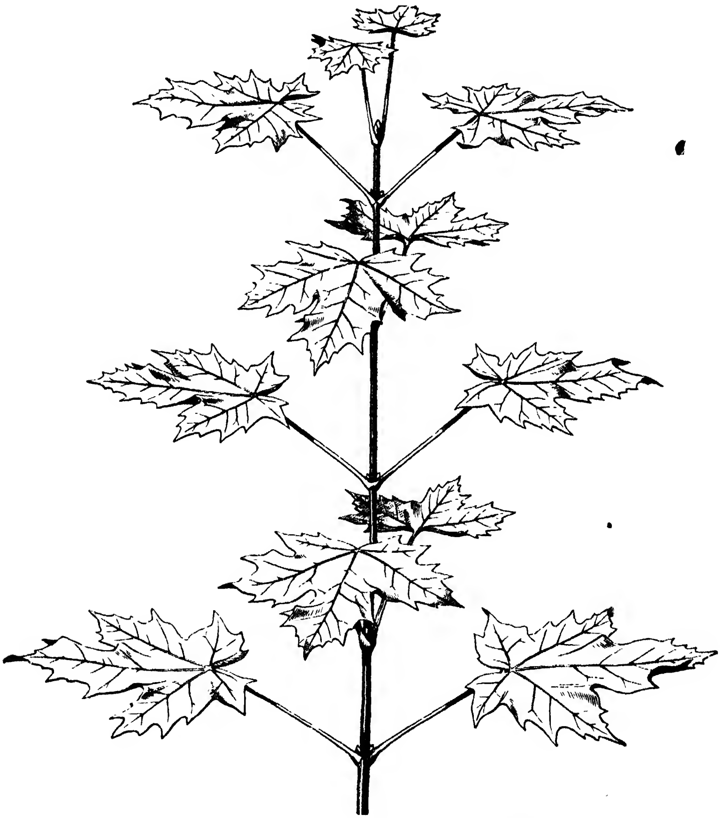

Fig. 1. Erect shoot of *Acer platanoides*, Norway Maple, viewed from the side and from above; showing the decussate arrangement and horizontal display of the leaves (K).

branches of the Silver Fir, the Yew, Chestnut, Box, Hazel, *Diervilla*, and many other plants, we find the leaves

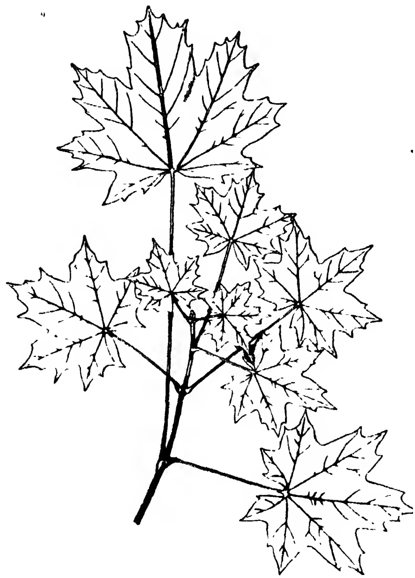

Fig. 2. Lateral horizontal shoot of *Acer platanoides*, Norway Maple, viewed from above and showing the arrangement and display of the leaves (K).

apparently arranged in a distichous manner, right and left on the branch, or in lateral series, as if combed to each side, though closer inspection shows that their phyllotaxy is quite different, and that the change in display is due to twistings of the petioles (Fig. 3).

Similar twistings are concerned in the disposition of the leaves of the Ivy, *Ficus repens*, and other plants which climb up walls, and those of prostrate plants, such as *Helianthemum*, *Salix repens*, *Lysimachia nemorum* and

others, including the Ivy (Fig. 27), when creeping on the surface of the soil.

There are other factors also of interest in these leaf-mosaics, but they do not concern phyllotaxy, and will be considered hereafter.

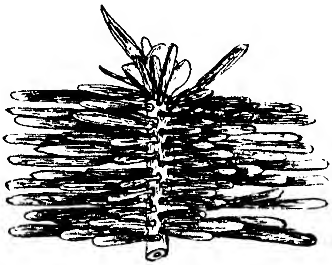

Fig. 3. Portion of shoot of *Abies*, viewed from above and showing the spirally inserted leaves combed to right and left in pseudo-distichous series (D).

It should, therefore, be observed that the adaptation of these leaf-positions to expose as complete a leaf-surface as possible to light and air, is the key to the whole subject. Beautiful examples of this fitting in of leaf by leaf are afforded by the Ivy and the Elm shown in Figs. 27 and 28.

The typical leaf is, in point of fact, "a trap to catch a sunbeam," and, as we shall see, its flat surface, thin texture, manner of support on the shoot, and the mode of exposure of the surface to the incident rays of the light from the sun, are only a few of the adaptations to this end, which are supplemented by many others all tending in the same direction. True, there are other subsidiary functions performed by leaves, which entail variations in their structure and form under special life-conditions, but these are not really opposed to the generalisation made above: they are in fact supplementary to them, as we shall see.

Meanwhile we may say that the principal varieties of leaf-insertion, with regard to the shoot, are as follows.

The leaves are opposite or decussate in

Clematis	Horse-chestnut	Field Maple
Norway Maple	Sycamore	Mistletoe
Dogwood	Elder	*Viburnum Lantana*
Aucuba	*Viburnum Opulus*	Honeysuckles
Symphoricarpos	*Thuja*	*Cupressus*
Lilac	Ash	Privet
Loiseleuria	Ling	Box.

The leaves are alternate and spirally disposed in

Barberry	Bilberry	Tamarisk
Holly	*Rhamnus*	Furze
Whin	Broom	Robinia
Laburnum	*Prunus*	*Pyrus*
Roses	Hawthorn	Blackberry
Ribes	*Arbutus*	Rhododendron
Azalea	*Daphne*	*Hippophaë*
Myrica	Alder	Birch
Walnut	Oaks	Poplars,

and in most Willows and Conifers.

The leaves are alternate and distichous in

Lime	Vine	Virginian Creeper
Planes	Ivy	Cranberry
Elms	Hornbeam	Chestnut
Beech	Hazel	Cherry Laurel.

The leaves are in whorls of three or four in

Erica tetralix	Juniper	*Erica ciliaris*
Erica cinerea	*Empetrum*	*Erica vagans*
Erica carnea.		

CHAPTER II.

FORM AND COMPOSITION OF LEAVES.

Petiole and lamina—Venation—Simple and compound leaves—Petiolate and sessile leaves—Sheath—Stipules—Outline of the lamina—Types of form—Margin—Apex—Types of simple leaves.

ON regarding a typical foliage-leaf, such as that of the Ivy, Aspen, Lime, Pear, or Plane, for example, the student at once distinguishes two parts, the leaf-stalk or *petiole*, and the blade or *lamina*. The former may be long or short, and the latter may be large or small and variously shaped, but it is characterised chiefly by being thin and expanded, and is joined to the leaf-insertion by the petiole.

The lamina is the essential part of such a leaf, and the petiole is merely a support and connection for it. Somewhat closer inspection of the lamina discloses the existence of a more or less copiously branched system of *ribs* or *veins*, buried in the softer green structure (mesophyll) of the lamina, and evidently of the nature of strands or cords of a tough consistency that resists tearing, which run down the petiole to the stem on which the leaf is inserted: this *venation* may usually be seen more clearly in thin leaves by holding the leaf up to the light, and its comparative toughness is detected by tearing the lamina

between the fingers, when the venation is found for the most part to resist the strain much better than the softer tissues in which it runs.

If, still confining our examination to the ordinary green foliage-leaves, we compare a large number of different kinds, selected from common plants, a broad distinction between two great categories of leaves rapidly forces itself upon our attention. While many of them agree with those mentioned in having a simple and undivided, or unbranched, lamina, others are found to have the lamina more or less cut up into segments, or to be branched in various ways.

Everyone would at once distinguish sharply between the *simple* leaves of the Bay Laurel, Beech, Nettle, Bamboo, Water Lily and *Rhododendron*, for instance, on the one hand, and the *compound* leaves of the Horse-chestnut, *Laburnum*, *Robinia*, Ash, Sensitive Plant, and Maidenhair Fern on the other; insisting on the fact that whereas the former present in each case a definite whole, with one blade and one stalk only, the latter are more or less obviously branched so that several blades are fixed on to a common stalk, from which they can be detached one by one.

If we extend our comparison to leaves such as those of the Oaks, White Poplar, *Pyrus torminalis*, Fig, Hawthorn, and some others, however, it becomes evident that a series of examples can be selected which commence with perfectly simple leaves and pass into compound ones by insensible gradations. Hence it is necessary in practice to take some mark by which we can distinguish the two kinds.

It is clear that the mere degree of incision of the leaf-blade does not decide the matter, for botanists term the leaf of the Celandine or the Hellebore simple, while that

of *Ailanthus glandulosa* or of the Horse-chestnut is compound.

The distinction rests rather on the jointing or articulation of the parts in the compound leaf, and we may generally employ this criterion as a test. The compound leaf, then, has the segments or branches (*leaflets*) of the lamina articulated more or less distinctly to the common

Fig. 4. Falling leaves of Horse-chestnut, *Æsculus*, showing disarticulation of leaflets from rachis (K).

leaf-stalk (*rachis*) and devoid of any trace of lamina at the place of junction, and these leaflets can therefore be pulled away easily, leaving a scar where they were joined. This is readily detected when such compound leaves fall in the autumn, each segment coming off separately and leaving a distinct scar (Fig. 4).

The distinction between compound and simple leaves is only of value on account of the enormous variety of leaves to be described, and is somewhat arbitrary, the whole matter really turning on the branching of the leaf.

The leaves are compound in

Clematis	Mahonia	Horse-chestnut
Ailanthus	Virginian Creeper	Robinia
Laburnum	Blackberry	Roses
Dewberry	Sweet-briar	Raspberry
Rowan	Elder	Service Tree
Ash	Walnut.	

In certain other cases, such as the Barberry, Broom, Gorse, and Whin, close observation is needed to determine the compound nature of the small or altered leaves.

In the rest of the trees and shrubs to be considered the leaves are simple.

The typical simple leaf, then, commonly exhibits a blade or *lamina*, and a stalk or *petiole*, and is said to be *petiolate* (Fig. 5). In some cases, however, the petiole is absent, and the lamina is *sessile* on the leaf-insertion, as in many species of *Hypericum* and Honeysuckle, and in the Juniper; such sessile leaves are, however, rare in our trees and shrubs. According to the expanse of the insertion, and the consequent partial or complete surrounding of the axis by the mesophyll, or softer green tissue of the leaf, the following cases are distinguishable:—

The particular case where opposite leaves are joined at their bases, so that the stem appears to pierce them, is termed *connate*, as in *Lonicera Caprifolium* (Fig. 54); and other similar examples are afforded by *Chlora perfoliata*, a herbaceous plant not uncommon in the fields.

When the petiole is present it may be long or short, stout or slender, cylindrical, or not: very often it is

channelled above, as in the Ash, and the transverse section is then more or less crescentic. In the Aspen and some other Poplars the petiole is flattened from side to side. In some species of *Lathyrus* and others the petiole is

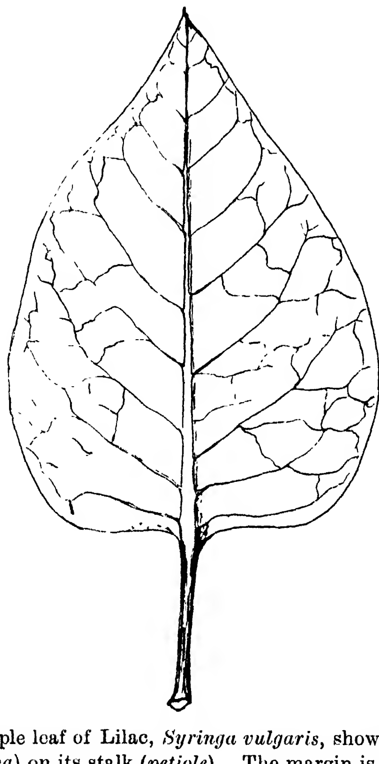

Fig. 5. Simple leaf of Lilac, *Syringa vulgaris*, showing heart-shaped leaf-blade (*lamina*) on its stalk (*petiole*). The margin is entire (D).

winged, the mesophyll of the leaf being continued down the sides as thin plates.

There can be little doubt that long and flexible petioles enable the lamina to take shocks of hail, rain, wind, &c.,

and to obtain light and air more advantageously, and so favour the leaf.

The insertion of the petiole on the stem may be narrow and small, or broad and large; and when the leaf falls the scar or *cicatrix* left on the stem is often very characteristic in shape, e.g. *Magnolia*, Ash, Horse-chestnut, Hickory, *Platanus*, Walnut, details of use in determining the species of deciduous trees in the winter, as explained in Vol. I. p. 118.

In many Ranunculaceæ, Umbelliferæ, &c., the base of the petiole is so dilated that it surrounds the stem more or less completely with a membranous *sheath*, which often carries the point of divergence of the petiole some distance above the nearly circular insertion. Such a sheath is still more conspicuous in the case of Grasses and Sedges, where it often surrounds the stem like a long rolled-up cylinder, and passes above either into a very short true petiole (*Bambusa*) or, more usually, directly into the lamina and constitutes all that there is to represent the petiole.

The leaves of Mahonia are also *sheathing*, the base being somewhat wrapped as it were round the stem.

In a large number of cases, again, the base of the petiole has two lateral appendages flanking it, and so far recognisable as distinct organs, more or less leaf-like in character, that they must be distinguished by the name of *stipules*. These stipules vary much in size, shape, position, and degree of segmentation; and as they often serve special purposes, such as protection of tender young organs, and aid in the diagnosis of whole families of dicotyledonous plants, they have received considerable attention from botanists.

Stipules may be *free*, as in the Elm, Quince, &c., or *adnate* to the petiole, as in the Clover, Rose, &c., or they may be so completely united to the latter and to each

other as to form a peculiar sheath or *ochrea* round the internode above the leaf-insertion, as in *Polygonum*, Rhubarb, and other Polygonaceæ.

While in many cases they are so small as to be easily overlooked, e.g. in Barberry, Mahonia, and in the Holly, where they can only be detected by microscopic examination in the bud; they are in others so readily cast (*caducous*) that their existence may be unsuspected unless the student examines the shoot as it emerges from the bud. This is particularly the case in many Willows. Careful scrutiny of the bases of young leaves with a lens will frequently enable us to detect the two minute lateral scars left on the fall of the stipules, just as surely as we can detect those of the larger leaf-scars themselves—e.g. Beech, Elm, Hornbeam. The following plants have no stipules at all to their leaves, which are therefore said to be *exstipulate*, or they are so minute and fall off so early as to be practically absent (*obsolete*):—

Clematis	Tamarisk	Horse-chestnut
Sycamore	Field Maple	Norway Maple
Ailanthus	Furze	*Genista anglica*
Ivy	Mistletoe	Dogwood
Honeysuckles	*Aucuba*	*Symphoricarpos*
Holly	Arbutus	Rhododendron
Lilac	*Lycium*	Ash
Privet	Bittersweet	*Daphne*
Hippophaë	Box	Pines
Larch	Firs	Spruces
Cedars	Junipers	Yew
Thuja	*Cupressus*	Heath
Bilberry	Cranberry	Ling.

In the following the stipules are more or less persistent and evident on the mature leaf:—

Rhamnus Frangula	Robinia	*Sarothamnus*
Laburnum	Prunus Padus	Blackthorn
Cherry	*Prunus Avium*	Roses
Blackberry	*Viburnum Opulus*	*Salix triandra*
Salix pentandra	*S. Caprea*	*S. aurita*
S. cinerea	Hazel	Hornbeam
Birch	Alder.	

The following have deciduous or caducous stipules, i.e. they fall at once on or soon after the emergence of the leaf from the bud:—

Tilia	*Ampelopsis*	Vine
Spindle Tree	*Rhamnus Catharticus*	Pear
Apple	*Pyrus torminalis*	*Pyrus Aria*
Rowan	Hawthorn	Black Currant
Gooseberry	Red Currant	*Viburnum Lantana*
Elder	Elms	Poplars
Oaks	Beech	*Salix fragilis,*

and many other Willows.

If the student collects a number of common simple leaves, noticing at the time that he is taking average specimens of the foliage, he soon becomes convinced that there is some relative stability of form, and that a type-shape can be chosen for each kind from which the rest of the foliage does not usually depart very much. Absolute geometrical constancy he will not find, and some plants show far more variety than others; but in cases like the following, most of the leaves on the plant or tree will be found fairly exemplified by any normal specimen.

Suppose we take average leaves of Scotch Pine, Yew, *Hypericum*, Beech, and common garden Nasturtium (*Tropæolum*), we shall find that they conform most nearly to the following geometrical outlines, termed *acicular*, *linear*, *oblong*, *oval* (or elliptical), and *sub-rotund* in order

of the numbers in Fig. 6, and it is advisable to observe these terms and consistently use them for such cases.

Leaf-outlines, however, are rarely so simple as this, and one of the commonest modes of departure from the fundamental form is due to the *base* or *apex* (or both)

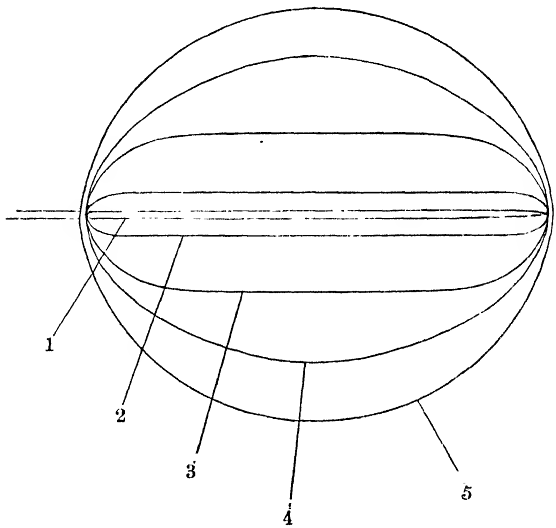

Fig. 6. Outline-forms of simple leaves. 1 *acicular*; 2 *linear*; 3 *oblong*; 4 *oval*; 5 *sub-rotund*. The petiole and base to the left.

of the lamina being broader or narrower than in the geometrical figure which the outline as a whole suggests. Thus, the leaves of most Grasses taper too much and too gradually to be called simply *linear*; those of the Sallow are too broad at the base to be termed purely *oval*; and those of *Salix herbacea* though often nearly *rotund* are not so exactly so as the type chosen above.

To provide for these and similar cases, which occur

very often, botanists accept the following derived figures (Fig. 7).

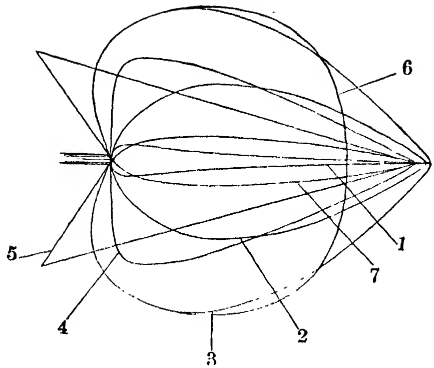

Fig. 7. Outlines of leaves. 1 *subulate*; 2 *ovate*; 3 *cordate*; 4 *deltoid*; 5 *sagittate*; 6 *reniform*; 7 *lanceolate*. The petiole and base to the left.

Here we see the base is broader than the apex, or may be drawn out as it were into rounded or acute corners, giving *subulate* (1), *ovate* (2), *cordate* (3), *deltoid* (4), *sagittate* (5), *reniform* (6), *lanceolate* (7) as easily recognised types.

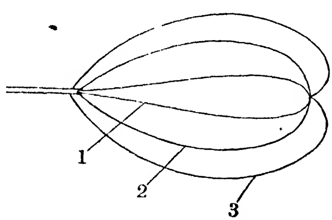

Fig. 8. Outlines of leaves. 1 *spathulate*; 2 *obovate*; 3 *obcordate*. Petiole and base to the left.

In another series of cases the fundamental simple geometrical form is modified by the apex instead of the

base being the broader, as in the leaves of the Daisy, Alder, or the petals of a Dog-rose, &c. (Fig. 8), and the terms *spathulate* (1), *obovate* (2), and *obcordate* (3) are in general use.

The foregoing simple shapes, which may be regarded as fundamental simply in the sense that the outline figures of most leaves, &c., can be referred to one or more of them, concern the general outline only, and although other forms are occasionally met with, they may be considered as the commonest types.

Examples of leaves presenting linear, acicular, subulate, and similar forms, are afforded by the following:

The acicular type prevails in

Cedars	Douglas Fir
Spruce	Pines.

The linear type prevails in

Silver Fir	*Erica vagans*	Heath
Larch	Yew	*Salix viminalis*
Crowberry	Bell Heather	*Erica carnea*
Sea Buckthorn.		

The subulate type is rare, but occurs in

Juniper	Tamarisk.

The lanceolate type of leaf-form occurs in the following:

Narrow lanceolate in

Andromeda	Weeping Willow	Crack Willow
White Willow	*Salix purpurea*	*Salix vitellina.*

Broader lanceolate in

Aucuba	Privet	Portugal Laurel
Chestnut	*Lycium*	Almond
Salix triandra	*Azalea*	Spindle Tree
Cherry Laurel	*Rhododendron*	Sweet Gale
Mezereon	Spurge Laurel.	

The oblong type of leaf-form is not common, but it occurs in

Box	*Quercus Cerris*	Buckthorn
Salix Lapponum	Robinia	Bearberry
Mistletoe	Hornbeam	Oaks
Cowberry	*Salix herbacea*	*Arbutus.*

The elliptic type of leaf-form is to be found in

Beech	White Beam	Walnut
Laburnum	Cotoneaster	Fly Honeysuckle
Dogwood	Buckthorn	*Symphoricarpos*
Honeysuckle	*Salix reticulata.*	

The sub-orbicular type of leaf-form may be found in

Raspberry	*Salix reticulata*	Pear
Aspen	*Salix herbacea*	Cotoneaster
Hazel	Lime	Honeysuckle.

More or less typically ovate leaves and leaflets are common, and occur in

Raspberry	Bilberry	Virginian Creeper
Dogwood	Blackberry	Cherry
Bittersweet	Buckthorn	Bay Willow
Ivy	Pear	White Poplar
Elms	Mulberry	*Salix phylicifolia*
White Beam	Apple	Cranberry
Blackthorn	Sallow	Mahonia
Bird Cherry	Gean	Wayfaring Tree
Honeysuckle.		

Typically obovate leaves and leaflets are less common, but may be found in

Horse-chestnut	*Salix aurita*	Wych Elm
Sarothamnus	*S. lanata*	Gean
Oak	*S. reticulata*	Buckthorn

White Beam	*Salix nigricans*	Cowberry
Alder	Honeysuckle	Bearberry
Blackberry	*Vaccinium uliginosum.*	

Cordate, or heart-shaped leaves, occur in

Lilac	Birch	White Poplar
Raspberry	Lime	Red Currant
Service Tree	Blackberry	Black Currant
Black Poplar	Ivy	Elm
Mulberry	Canadian Poplar.	

The deltoid or triangular type is uncommon, but may be met with in

Black Poplar	Mulberry	White Poplar
Service Tree	*Thuja*	Gooseberry
Ivy	Birch	Canadian Poplar.

It is important to notice, however, that it rarely occurs that a leaf can be completely described, as to its outline, by one term. It is a common event to find, for instance, a leaf which is too nearly elliptical to be termed ovate, and too broad near the base to fit into an ellipse: the compound word *elliptic-ovate* may, however, describe it accurately. Or, again, suppose we have a long thin leaf, such as that of the Osier. Its sides are too parallel for a long distance to be termed lanceolate, though its ends taper too much for the word linear to apply: the compound *linear-lanceolate* may fit the case exactly, and, as will be seen in Part II., these combinations of terms are necessary in by far the majority of cases.

Another difficulty for the beginner resides in leaves which are so lobed, or divided into segments, at the margins, that he hesitates how to begin the description. The rule is to suppose a contour line drawn so as to include the base and apex, and touch the tips of all the lobes. In most cases a figure perfectly describable in

terms such as I have enumerated will be obtained, and the further analysis can be attempted.

In compound leaves, the terms referred to are applied to the leaflet.

A number of other useful terms will be employed as we proceed, and their explanation is given in the glossary.

But we rarely find that the circumscription of a leaf would accurately describe its shape in terms of the above figures only, and the *margin* and *apex* especially usually need additional description.

The margin (Fig. 9), if unbroken, is termed *entire* (1); but it is more commonly *serrate* (2), *dentate* (3), *crenate* (4), *sinuate* (5), or *cut* (7) in various degrees; the *serrate*

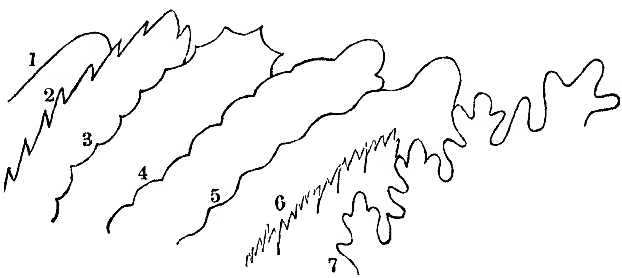

Fig. 9. Margins of leaves. 1 *entire*; 2 *serrate*; 3 *dentate*; 4 *crenate*; 5 *sinuate*; 6 *bi-serrate*; 7 *cut* or *lobed*.

margin being very common, and defined by the saw-like teeth pointing forwards. When the serrate teeth are again serrate, as in Fig. 9 (6), the term *bi-serrate* is used.

The apex (Fig. 10) may be bluntly rounded, or *obtuse* (1), or pointed in various ways—e.g. *acuminate* (2), or merely *acute* (3), or *mucronate* (4), or *retuse* (5), all of which occur more or less commonly

The art of describing a leaf well and accurately depends on the judicious use of such terms as the above, especially in combination—e.g. *ovate-lanceolate, linear-oblong*—when the form approximates both of the outlines

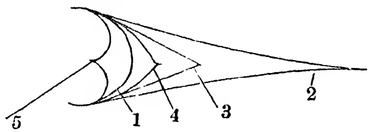

Fig. 10. Apex of leaves. 1 *obtuse*; 2 *acuminate*; 3 *acute*; 4 *mucronate*; 5 *retuse*.

involved, and considerable differences in the use of the terms are indulged in by descriptive botanists of various degrees of ability. As a rule the student will find the really good observer uses terse and crisp terminology with great effect, once the meaning of the terms is understood; and he should study the work of a good descriptive botanist with a view to modelling his style of description on it.

These illustrative examples of outline, margin and apex, have to be supplemented in descriptions by details as to the *venation, surface, texture,* and even the *colour* and other particulars in some cases.

Examples of entire leaves are afforded by

Laburnum	Walnut	*Symphoricarpos*
Robinia	Thuja	Juniper
Mistletoe	Box	Cypress
Dogwood	Honeysuckle	*Loiseleuria*
Privet	Lilac	Cranberry
Mezereon	Bittersweet	Spurge Laurel
Salix viminalis.		

Examples of dentate leaves are found in

Barberry	Chestnut	Plane.

Examples of acute apex occur in

Elder	Walnut	Wayfaring Tree
Spindle Tree	Rowan	Dogwood
Mistletoe	Heather	Sallow
Privet	Bittersweet	*Symphoricarpos*
Hornbeam	Apple	Beech
Blackthorn	Plum	*Arbutus*
Bilberry	Cross-leaved Heath.	

The acuminate apex is common in

Ash	Birch	Virginian Creeper
Thuja	Bird Cherry	*Salix pentandra*
Hazel	Aucuba	*S. daphnoides*
Crack Willow	Buckthorn	*S. viminalis*
Gean	Lime	*S. purpurea*
Lilac	Black Poplar	Elms
White Willow	Cherry	Horse-chestnut.

Examples of obtuse apex occur in

Robinia	Crowberry	Sea Buckthorn
Loiseleuria	White Beam	Ling
Pear	Bog Myrtle	Aspen
Cotoneaster	*Salix herbacea.*	

The retuse apex occurs in

Robinia	Cowberry	*Salix retusa*
Silver Fir	Alder	*S. reticulata*
Box	Bog Whortleberry.	

The mucronate apex may be found in

Laburnum	Cotoneaster	Douglas Fir
Cypress	Robinia	Spruce
Fly Honeysuckle.		

Examples of leaves serrate in various degrees occur in

Elder	Mulberry	Virginian Creeper
Ash	Rowan	Horse-chestnut

Currants	Aucuba	Crack Willow
Ling	Heather	Portugal Laurel
White Willow	Gooseberry	Bird Cherry
Apple	Vine	Blackthorn
Bird Cherry	Lime	*Salix pentandra*
Buckthorn	Almond	*S. daphnoides*
Hawthorn	Plum	*S. triandra*
Spindle Tree	Pear	Cherry Laurel.

Examples of bi-serrate leaves occur in

Raspberry	Blackberry	Hornbeam
Roses	Gean	White Beam
Hazel	Elms	Birch
Alder	*Arbutus*	Cherry
Service Tree.		

Examples of crenate leaves may be found in

Sallow	*Salix aurita.*

Examples of sinuate leaves occur in

White Poplar	Beech
Sallow	*Salix viminalis.*

Cut or lobed leaves are found in

Guelder Rose	Service Tree	White Poplar
Hawthorn	Ivy	Currants
Mulberry	Plane	Maples
Oaks	Fig	Vine
Gooseberry.		

Just as with contours, so with the margin, apex, base, &c., cases are common which require compound words for adequate description, e.g. the crenate-serrate margin of Portugal Laurel, or the spinose-dentate leaves of the Barberry; the cuneate-entire base of the Bog Myrtle, or the oblique-cordate base of the Lime; the pungent-acute

apex of Juniper or suddenly acuminate apex of *Salix pentandra*; and the art of good description depends on the judicious use of such terms in conjunction with what has gone before.

Here also the terms selected are the principal necessary ones: reference to the figures and glossary will enable the student easily to apprehend a few others less generally needed.

CHAPTER III.

GENERAL CHARACTERS OF VENATION, SURFACE AND TEXTURE OF LEAVES.

Ribs and veins—They are water-pipes and distributors of liquids—Supporting system—Types of venation—Parallel and reticulate venation—Pinnate and palmate venation—Looped, infra-marginal, arcuate and other sub-types—Surface characters—Glabrous and hairy leaves—Forms of hairs—Texture of leaves.

ATTENTION has already been called to the series of conducting pipes and of supporting fibres which run as vascular bundles or strands through the soft tissues of the typical leaf, and which serve on the one hand to conduct fluids from stem to leaf and back again, and, on the other, to keep the collapsable tissues well expanded to the light and air, much as the silk of an umbrella is stretched on the ribs.

In conformity with this analogy, these vascular and fibrous strands of the leaf are called ribs and veins, and although the latter term is not free from objection, since it would seem to imply that the vascular tubes convey a circulating fluid like that of the blood in animals—which is emphatically not the case, because the watery liquids contained in the leaves are very different in origin, constitution, movements and functions—the inexplicable

veneration attached to long usage of the terminology has to be respected, and botanists all over the world term the network referred to, the venation of the leaf.

As a rule we can distinguish in the larger leaves of trees and shrubs a midrib, giving off secondary ribs, which break up into smaller and smaller tributaries or subordinate branches termed veins; these latter usually breaking up into still smaller ramifications arranged in a more or less definite and complex network, the ultimate ends of which lose themselves as blind ends in the soft tissues of the leaf. Hence any watery liquids brought up the petiole and midribs from the stem can be distributed to every part of the leaf by smaller and smaller veins, just as the water system of a town distributes the liquid through more and more numerous and narrower pipes, from the great supply pipes to the houses; or, in the reverse direction, the smaller veins gather up liquids from the leaf-tissues, and discharge them through the ribs to the other parts of the plant, much as the small drains of the houses collect liquids and discharge them through larger and larger drains into the main sewers. Only, it must be noticed, first, that the liquids thus collected in the leaf are not mere refuse, but are nutritive in character; and, secondly, that the supporting fibres in the leaf accompany the conducting vessels, an arrangement not common in engineering, unless we compare it with what occurs in viaducts and similar structures, where the girders, &c., would represent the fibres.

The venation in the vast majority of leaves conforms to two principal types. It is either *parallel*, where all the principal veins run for relatively long distances in straight or nearly straight and parallel lines, as in Grasses, Lilies, Orchids and Monocotyledons generally; or *reticulated*, where they exhibit an evident network made up of

curved lines and cross-connections, as in most Dicotyledons—e.g. Sallow, Maple, Poplar, Oak, &c.

On closer examination, however, we find that several different plans of distribution can be made out in each of these types, some of the commonest of which are the following.

In reticulately veined leaves the midrib or principal axial strand, which runs through the centre of the leaf, is usually distinct from the secondary ribs, and these occur in two chief forms. In the Beech, Elm, Hornbeam, Chestnut, &c., the secondary veins run out from the midrib like the plumes of a feather, and the type of venation is *Pinnate*; but in Maples, Plane, Nasturtium, Currant, Mallow, &c., several strong veins diverge as they enter the lamina with the midrib, somewhat as do the fingers of an open hand, and the venation is termed *Palmate.*

In parallel venation, too, a distinction must be drawn between the *longitudinally parallel* venation of Grasses, Orchids, &c., where all the principal veins run parallel to the midrib or nearly so, and the *obliquely parallel* venation of *Musa*, Ginger, *Revenala, Elettaria* and a number of other tropical Monocotyledons, where the secondary veins leave the midrib as in the pinnate type, and run in obliquely parallel straight lines to the margin.

The further course and mode of ending of the secondary and tertiary veins in reticulately veined leaves give other characters worth noting—e.g. in *Rhamnus Frangula, Prunus Mahaleb,* Docks, &c., each secondary vein curves upwards and inwards before reaching the margin and forms an arched loop with the next one above (*looped* venation): in the Myrtle and Forget-me-not these loops are so flat that the appearance of an *infra-marginal vein* is produced, owing to their junction and course along the edge.

In the Cornels the lower secondary veins curve upwards

but do not directly join, nor do they reach either margin or apex; this *arcuate* venation is also characteristic of *Melastomaceæ*, where, however, they curve into the midrib above.

In the case of pronounced pinnate venation, characters of systematic value can also be obtained according as the secondary veins run straight to the margin and there end in the tip of a lobe or tooth, or in the sinus between two lobes or teeth. For instance, they end in the lobes or teeth in Oak, Alder, Hazel, Elm, Chestnut, and other trees and shrubs; but in Rhinanthaceæ they end between.

The palmate or radiate type of venation offers similar variations. Thus the leaves of *Cercis* are *palmate-reticulate*; those of some Water Lilies are *palmate-looped*; those of our ordinary trees and shrubs with palmate venation, where the principal veins radiate but are themselves pinnate, may be termed *palmate-pinnate.*

Among parallel-veined leaves we also find several subtypes. In the first place a distinction must be drawn between *pseudo-parallel* venation as met with in *Plantago*, *Bupleurum* and other leaves, where the venation as a whole is evidently really reticulate, because the smaller veins form visible cross-ties which net together the larger ones; and also between the *curved-parallel* venation of Lily of the Valley, *Polygonatum, Listera, Potamogeton,* &c., as contrasted with the *straight-parallel* venation observed in Grasses, Sedges, &c. Though even here there are a few invisible cross-ties.

The *fan-like* venation of many palms also affords a good character; as also does the *furcate* venation of many Ferns, *Ginkgo*, &c.

Other points to notice regarding venation are whether it is *prominent* as in the Sallow, or *immersed* as in thick fleshy leaves like *Sedum,* and leathery leaves such as those

of the Mistletoe, and many Conifers. In the narrow leaves of the latter, e.g. Pines, Firs, Cedars, &c., and in some small leaves of other plants there is only one vein, the midrib.

These matters are by no means trivial, and the student should understand that not only does venation yield valuable species-characters, as we shall see further on, but that good service has been rendered to palæontology by applying what is known regarding living species to the impressions of fossil-leaves found in the rocks, and so at least helping the avoidance of error.

The surface of the leaf, apart from microscopic characters, usually presents itself as hairy or devoid of hairs; in the latter case it is termed *glabrous*. This term does not necessarily mean smooth, in the sense of being shiny or glossy, but simply devoid of visible hairs, and when the glabrous surface is also especially smooth and shining, the terms *polished* (Ivy, Holly, &c.), or *varnished* (Coffee, *Salix pentandra*) may be employed.

As a general rule the upper and lower surfaces of a leaf differ in respect to these matters: the latter being usually duller and paler in hue, and often hairy when the upper surface is glabrous; or covered with a waxy bloom, giving it a sea-green (*glaucous*) appearance, while the upper surface is deep or bright green. It is also a common event to find the venation prominent below, and scarcely visible above; while in other cases the softer parts of the leaf are puckered up between the veins so that the latter appear sunk in the tissues above and protrude below, as in the Sallows, when the leaf is termed *rugose*, or wrinkled.

The different forms of hairs and degrees of hairiness have already been referred to in Vol. I. pp. 85—92. The principal varieties met with in the leaves of such trees and shrubs as we are here concerned with are, *pubescent* or slightly and softly downy as in Red Currant; *silky* as

in Laburnum and White Willow; *pilose* or velvety and almost woolly as in Apple; *tomentose* or densely woolly or cottony as in *Cotoneaster*, White Poplar, *Pyrus Aria*, &c.; *hispid* when covered with stiff bristly hairs as in many Boragineæ, or *scabrid* when the stiff hairs are shorter, giving a harsh feel, reminding one of a file, as in the Wych Elm and Fig.

In some cases the hairs are *glandular*, and secrete viscid substances, as in the Hazel; in others they are more or less *stellate* as in the Plane and *Viburnum Lantana*; or they are *peltate* and scale-like, giving the leaf a peculiar glistening scurfy appearance, often silvery or bronzed, as in *Hippophaë* and *Eleagnus*.

Hairs fringing the margins render the latter *ciliate*, as in the Beech, where the young leaves are ciliate with silky hairs: in the Barberry the slender teeth similarly render the margins *ciliate-dentate*, while in the Holly the margin is *spinose*, owing to the outstanding prickly teeth.

The ordinary thin green leaf is *membranous* or *herbaceous*, as in the Plane, Norway Maple, Dogwood, &c.; or it may be thicker and soft, or *fleshy*, as in many Crassulaceæ, *Sedum*, &c., passing to a more leathery texture, as in Mistletoe, Holly, Pines, Firs, &c., when it is termed *coriaceous*.

Leaves marked with spots or blotches of different colours are *maculate* or *variegated*, as in the Arum, Orchids, *Aucuba* and many cultivated forms of Holly, Ivy, Maples, &c. These cases must be distinguished from blotching and spotting due to disease-fungi and other pathological conditions. In some cases the leaves have purple or red under-surfaces as in some Sycamores; or the whole leaf assumes such colours, as in the Copper Beech. Here again we must carefully distinguish between the discolorations or bright hues of normal leaves, and those due to the moribund tissues of autumn leaves.

CHAPTER IV.

DIVIDED AND COMPOUND LEAVES.

Development of the leaf—The branching of the leaf—Teeth and lobes—Venation—Pinnate and palmate types—Incision of the leaf—Compound leaves—Segmentation—Rachis, petiolule, pulvinus, &c.—Leaflets—Description of compound leaves—Types of pinnate, palmate and tri-foliolate compound leaves—Types of simple lobed leaves.

THE development of the young leaf in the bud shows us that it always arises as a small hump of tissue on the side of the more or less pyramidal end of the shoot-axis. See Vol. I. Chap. IV. As this hump grows larger it expands more and more according to the type of lamina to be formed. If this is small and entire, the process of shaping is comparatively simple; but in many cases the expanding leaf-incept soon begins to grow more rapidly in certain directions from various points on its margins. This branching of the leaf—for that is what the process really amounts to—may be very slight, and result in nothing further than the small marginal irregularities we have termed teeth, and the leaf ends by being simple and dentate, serrate, crenate, &c., as shown in Fig. 9.

If the branching of the lamina goes further, and puts out prominences too large, and involving too great a proportion of the margin to be termed teeth, we call them lobes, and the leaf is a simple lobed leaf (Fig. 11).

The arrangement of the lobes, and their sizes and numbers, differ in different cases.

The rule is that the type of venation is correlated with the type of lobing, and of these types there are, as

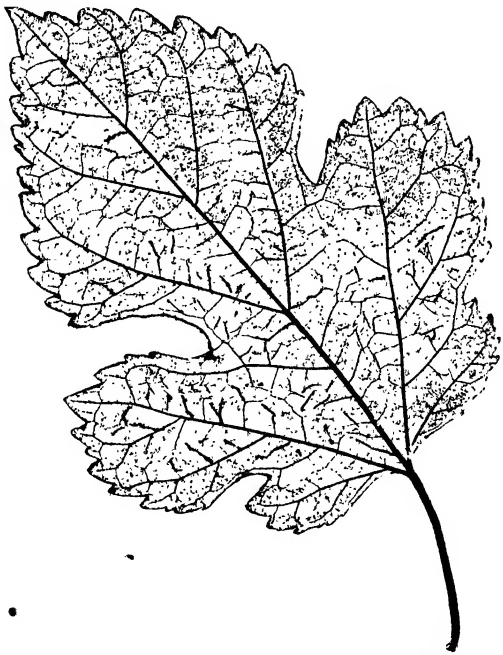

Fig. 11. Simple lobed leaf of the Mulberry, *Morus alba*.

we have seen, two principal forms. Leaves of the more elongated forms—I refer to the trees and shrubs with which we are here concerned—are apt to follow the pinnate type, the lobes being developed right and left along the leaf; one of the secondary ribs, also developed right and left along the midrib, passing into each, and

putting out its tertiary ribs and veins of various orders as it does so.

In the other type, the lobes diverge in a more or less radiating manner from the point in the base of the leaf where the petiole joins the lamina, and, as before, each similarly radiating principal rib passes up into a lobe. We thus get two types of lobing; palmately lobed and pinnately lobed leaves.

The next point for consideration is the relative sizes of the lobes themselves, or, as it is generally expressed—but erroneously—the relative depth of the incisions between the lobes into the lamina. If such incision only reaches about half-way from the general contour of the leaf towards the midrib, in pinnately lobed leaves, or towards the base, in palmately lobed leaves, the lamina is described as *pinnatifid* or *palmatifid* respectively; if the incision goes deeper the lamina is *pinnatisect* or *palmatisect*, or *partite* respectively, it being understood that in no case hitherto considered does the incision reach the midrib, or base, and completely cut off the lobe from other lobes. In other words, the green softer tissues of all the lobes are in continuity one with another by however narrow an isthmus of tissue at the bases of the incisions.

A step further, and the lobing or branching of the leaf is so complete that each segment—i.e. branch of the leaf—becomes independent of its neighbour, and stands off from the principal midrib of the leaf, or from the point of junction with the petiole at its base, as a separate *leaflet*, and the whole leaf is now said to be *compound*, pinnate (Fig. 12), or palmate (Fig. 13), as the case may be.

In such compound leaves the common or principal midrib, continuous with the petiole, is termed the *rachis*, and when, as often happens, each leaflet has its own little

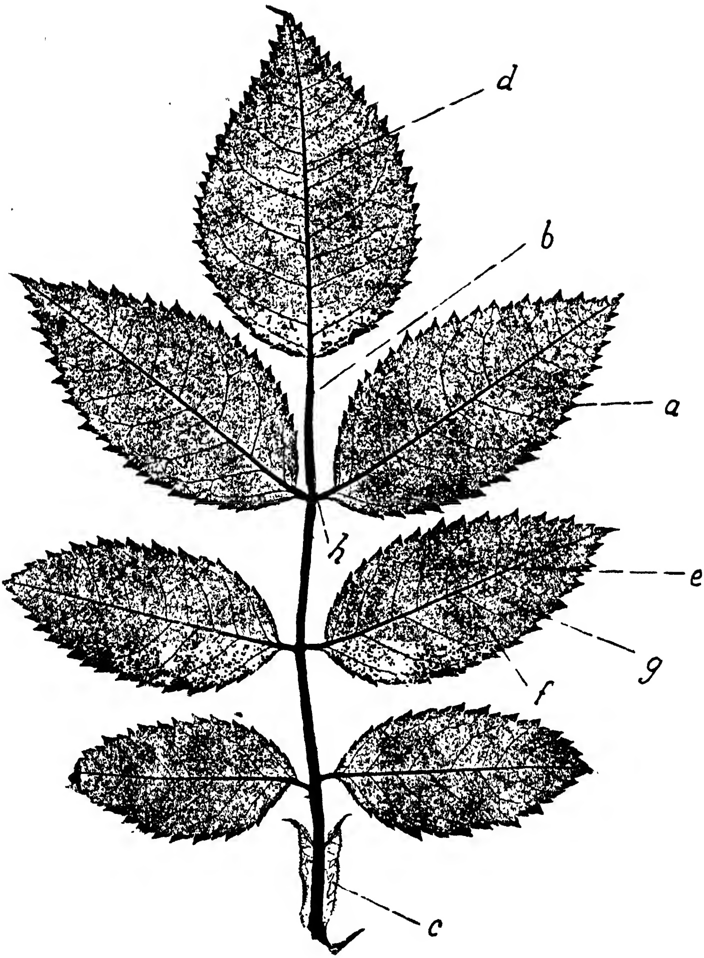

Fig. 12. Pinnate, compound leaf of Dog Rose, *Rosa canina*. *a* lateral and *d* terminal leaflet; *b* rachis; *c* adnate stipules. *e* midrib; *f* secondary and *g* tertiary veins of leaflet; *h* petiolule (Ett).

stalk attaching it to the latter, such stalk is termed a *petiolule*.

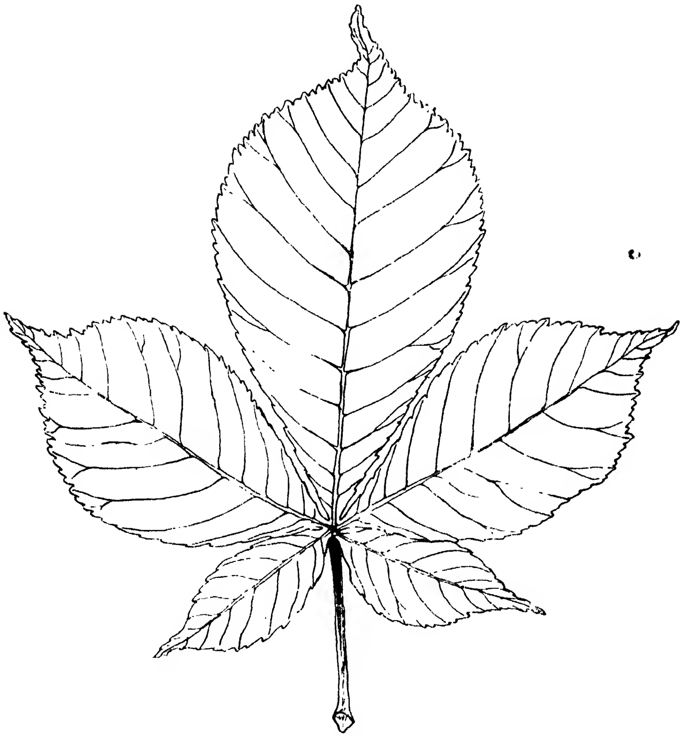

Fig. 13. Palmate, compound leaf of Horse-chestnut, *Æsculus Hippocastanum*, with five leaflets (D).

A conspicuous feature at the base of most compound leaves, and of many simple ones also, especially large leaves, is a cushion-like rounded swelling, the so-called *pulvinus*, particularly prominent on the lower side where the petiole abuts on the shoot-axis. This pulvinus is

known to be a motile organ, and consists of soft cellular tissue capable of taking up water into its cells, somewhat as a pump takes it up though the action is different in detail. When it becomes surcharged with water the pulvinus expands, especially beneath, and forces the petiole into a more erect position; when the pulvinus partially empties itself, the weight of the leaf compresses it, and the petiole falls, and considerable differences of angular divergence in the vertical plane may be undergone by the rigid petiole or rachis turning on its insertion as on a fulcrum.

Each leaflet may also have its own small pulvinus (*pulvinule*) at the base of its petiolule, and may similarly be raised and lowered according as the pulvinule is tense and full, or flaccid and partially emptied of water.

It will be understood that all the terms applicable to the contour, margin, apex, surface, &c. of a simple leaf are equally applicable to the individual lobes of a simple lobed leaf, and to the separate leaflets of a compound leaf; each may be of elongated, rounded, or angular shapes described on pp. 22 and 23, and each may be again lobed or segmented to any extent, or merely toothed, serrate, hairy or glabrous as before. In the case of compound leaves the leaflets may be again compound, though such is not the case in any of the trees and shrubs here to be dealt with.

Moreover, the petiolules of leaflets may be themselves provided with small stipules (*stipels*).

The number of leaflets in a compound leaf is in many plants constant or nearly so. In palmate leaves the number is commonly five, and the leaf is often termed *digitate*, with obvious reference to the hand, e.g. Horse-chestnut (Fig. 13), but three, seven, or more may occur, and a consistent terminology refers to such as *tri-*, *quinque-*,

or *multi-foliolate*, &c.; nor need the numbers be odd. A peculiar case is that of the *uni-foliolate* leaves of the Barberries and Oranges where one leaflet is attached by a distinct articulation to the petiole: each is therefore a compound leaf, but with only one leaflet.

In pinnate leaves, again, we may have *tri-*, *quinque-*, and *multi-foliolate* leaves, where one leaflet is odd and terminal; such leaves are termed *impari-pinnate*, e.g. Robinia. If the numbers are paired, and there is no odd terminal leaflet, the leaf is *pari-pinnate*, though such leaves do not occur among those here to be dealt with.

The case of the *tri-foliolate* leaf—e.g. Laburnum, Broom, &c.—requires careful examination. That it is a pinnate leaf is determined by the separate articulation to a slight stalk of the terminal leaflet; but it is easy for the student to be tempted to regard the whole leaf as of the palmate type if this point be overlooked.

It must not be supposed that the distinctions between simple lobed leaves and compound leaves are absolute, since plenty of examples can be selected where the upper part of a leaf is pinnatifid and the lower pinnate, e.g. in *Pyrus Aria*, Agrimony and other Rosaceæ, which only serves to emphasize the fact that the degree of segmentation of the leaf merely expresses the extent of its branching.

In the following examples it should be understood that the average type of the leaf is referred to; comparison of numerous leaves will show that considerable variation in contour and in details may be met with on one and the same plant, examples of which are very conspicuous in the Blackberry, White Poplar, *Pyrus Aria*, Fig, and Mulberry.

The leaves in the following are compound and pinnate:—

Clematis	Mahonia	*Ailanthus*
Robinia	*Rubus*	Roses
Rowan	*Pyrus Sorbus*	Elder
Ash	Walnut	*Rhus.*

The leaves are compound and palmate, digitate, &c. in

Horse-chestnut	Virginian Creeper.

The leaves are compound and tri-foliolate in

Furze	Broom	Whin
Laburnum	Raspberry	Blackberry.

The leaves are simple and palmately lobed, palmatifid, &c. in

Maple	Sycamore	Norway Maple
Vine	Gooseberry	Black Currant
Red Currant	Ivy	Plane.

The leaves are simple and more or less pinnately lobed in

Pyrus Aria	*Pyrus torminalis*	Hawthorn
Oaks	White Poplar	Fig.

CHAPTER V.

CHARACTERS OF THE VENATION IN DETAIL.

Ribs and veins—Primary, secondary and tertiary ribs, &c.—Terminals—Cross-ties and outer branches—Angles of divergence—Midrib or primary—Secondaries—Looping—Inframarginal vein—Leaf-areas—Tertiaries and veins of higher order—Reticulation—Examples of simple venation—Pinnate and strict-pinnate—Pinnate-looped—Pinnate-arcuate—Pinnate-reticulate—Palmate venation and its varieties.

The vascular bundles extending through the leaf-tissues are, as already stated, termed ribs and veins, and constitute the so-called venation. The principal ribs and veins usually project on the lower surface of the leaf, and are therefore easily visible there, but the finer veins are often invisible or inconspicuous, except in thin leaves and by transmitted light, because they are buried in the soft tissues. In leathery and fleshy leaves all but the strongest ribs are usually so buried and obscured.

The distribution and arrangement of the venation is by no means devoid of order, and is often very regular.

Bearing in mind that the ribs and veins are merely the upper ends of the vascular bundles of the stem, coming up the petiole and thence branching in the lamina, we distinguish these branches as of different orders, according to their thickness and relations one to another.

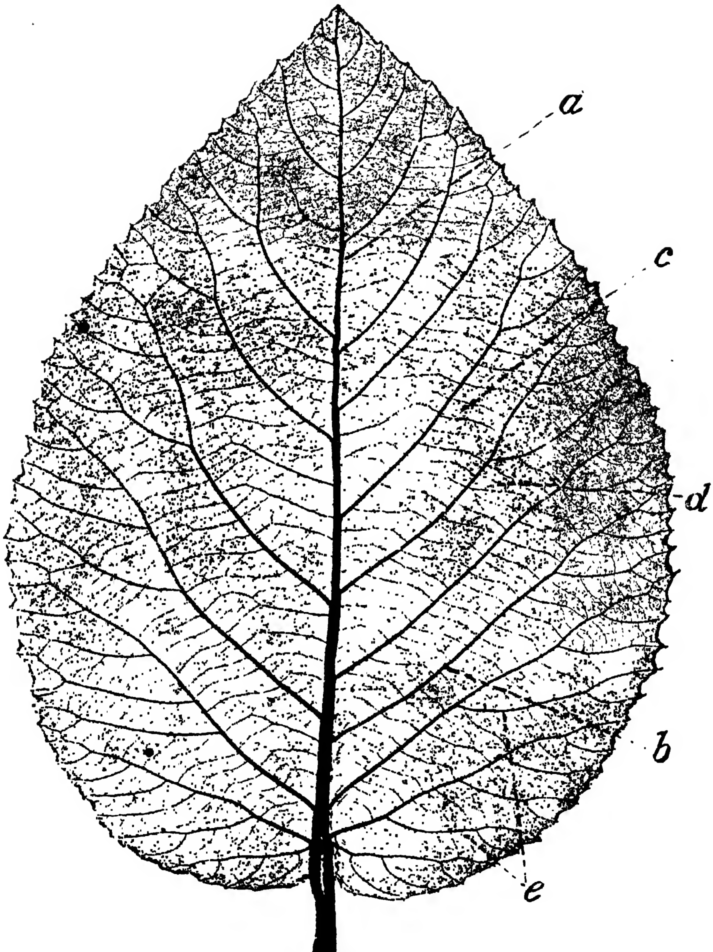

Fig. 14. Leaf of Wayfaring Tree, *Viburnum Lantana*, showing typical pinnate venation. *a* midrib; *b* secondary; *c* tertiaries, here forming cross-ties; *d* terminals; *e* outer branches of the secondaries (Ett).

The vascular bundles which come off as main strands from the petiole are termed primary, and these bear secondary strands, which in their turn branch into tertiary, &c., and so on, until the bundles of higher orders—generally the fourth or fifth—are too fine to follow. As a rule we do not enumerate any of higher order than the tertiaries, except that the blind ends of the last ramifications are called *terminals*.

In by far the majority of plants such as we have to consider, there is but one primary rib, the midrib, running vertically and continuously from base to apex of the lamina, and becoming thinner and thinner as it passes to the tip of the leaf; as it runs up it gives off secondary ribs from either side, of slightly narrower calibre than itself, which pass towards the margins, and in their turn give off tertiaries, &c., which break up into a less and less conspicuous meshwork. Such venation is termed pinnate, because the secondaries come off from the midrib somewhat as do the parts of a feather from the quill (Fig. 14).

In some broad leaves, however, the median primary or midrib is accompanied at its origin by two, four or more nearly equally strong ribs which divaricate from it, on either side, in their further course in the lamina, and since these lateral radiating ribs are usually quite as conspicuous up the median portion of each lateral lobe of the leaf—to each of which, in fact, one of them acts the part of a midrib to its lobe in the same manner as the central one does to the median lobe, or to the whole leaf—they may be regarded as primaries. Such venation, with several radiating primaries all springing from one point, is termed palmate (Fig. 15).

In particular cases, where these lateral primaries of a palmate venation need particularising, owing to differences

in their course, calibre, branching, &c., they may be referred to as lateral or as basal respectively. Each of them, as also the midrib, usually puts forth secondary ribs arranged pinnately up their sides, and these secondaries bear tertiaries, &c., breaking up into the finer reticulation as before.

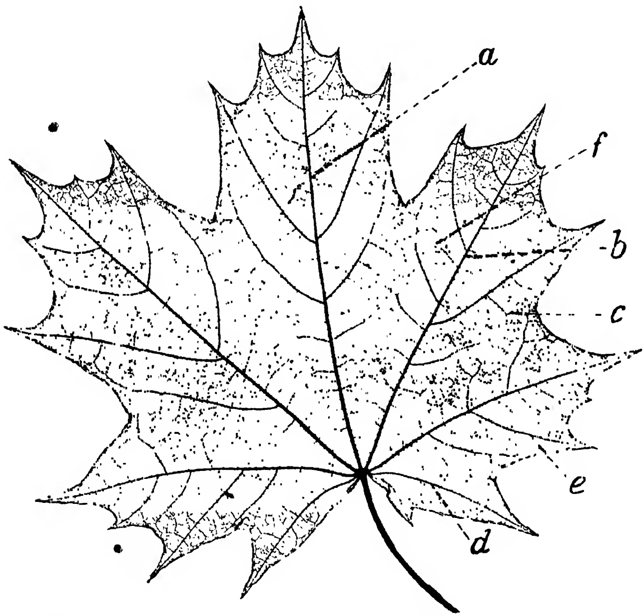

Fig. 15. Leaf of Norway Maple, *Acer platanoides*, showing typical palmate venation. *a* midrib; *b* lateral and *d* basal primaries; *c* secondary rib; *e* outer branches of primary rib breaking up into secondaries and reticulation (Ett).

Both in pinnate and in palmate venation the tertiaries from one secondary are apt to run across towards the next secondary and meet the tertiaries coming from it, forming

connections which serve as the boundaries of segmental areas which are the first larger meshes of the reticulations (Figs. 14 and 15 *c*); these meshes are then divided into smaller and smaller areas by further cross-connections in all directions of the branches of the tertiaries, and so on, the terminals standing out as blind ends in the ultimate meshes.

When, as often happens, the connecting tertiaries run across the area bounded by nearly parallel secondaries, and meet so as to form nearly straight ties, more or less at right angles to the secondaries, we may speak of them as cross-ties (Fig. 14 *c*).

Tertiaries from secondaries, or secondaries from primaries, are often stronger on the outer side of their parent strand than on the inner, and are worth distinguishing as outer branches, secondaries or tertiaries as the case may be (Figs. 14 and 15 *e*).

The relative thicknesses, lengths, distances apart, angles of divergence, course and direction of the secondaries and tertiaries, as well as the shapes of the areas or meshes enclosed by them, often afford useful characters in distinguishing leaves, but it is in very rare cases only that the characters of ribs or veins of higher order can be utilised.

Confining our attention solely to such trees and shrubs as are concerned in this book, the following details of venation will be found instructive and useful for our purposes.

The primary rib may be strong, as is usually the case with the midrib of ordinary leaves, or weak, and frequently tapers from a strong basal to a capillary apical portion. It is usually straight in course, but not always, and may be undulating. In by far the majority of cases it runs right up to the tip, and may be prolonged into an

apical subulate tooth, e.g. *Quercus coccinea*. In most cases, also, it divides the lamina into two equal halves—i.e. it is strictly median—but there are exceptions, e.g. Lime, and especially some tropical plants.

The secondary ribs offer diagnostic characters of some importance in the angle of divergence from the primary ribs. This angle may be small—less than 45°—but in the majority of cases it approaches 55° on the average, e.g. *Castanea*: it is however occasionally a right angle, and in rare cases is greater than a right angle with the forward part of the midrib. Moreover the upper secondaries often come off at a different—usually more acute—angle than the lower.

As with the primaries, so with the secondaries, we have strong, weak and excessively fine strands in different species.

Their length is best expressed in terms of the breadth of the leaf, or of the length of the midrib: it refers to that part of the secondary which can be distinctly traced from its origin to where it breaks up above into the network. As regards their length, relative to each other, the secondaries near the middle of the leaf are usually the longest, those above rapidly and those below gradually becoming shorter; but plenty of cases occur where the upper secondaries are longer, and even where secondaries exceed the midrib in length.

Very useful characters are derived from the direction and course of the secondaries. They may run quite straight to the margins, as in the Hornbeam, Chestnut, &c., or curve out in more or less divergent lines, as in the Beech, or convergent, as in the Birch, or they may be sinuous, as in *Quercus coccinea*.

The rule is that they thin off gradually, but in some cases the ends suddenly thin out to capillary veins.

They may run as simple strands to the margin, e.g. Beech, or soon branch at the ends and rapidly break up into a network of fine capillaries, e.g. Pear. In many cases the secondaries, or some of them, give rise on their outer sides to branches but little weaker than themselves, and these outer veins are very characteristic—e.g. Alder, Elm, Hazel, Lime: they sometimes give a forked appearance to the secondaries, e.g. Wayfaring Tree (Fig. 14).

Even more characteristic is the common case where each secondary curves forwards and inwards at its upper end, and joins on to the next anterior secondary, as by a loop, more or less strongly convex to the margin, e.g. *Prunus spinosa*, Honeysuckle, and since this looping of the secondaries is often a conspicuous feature, and absent from or obsolete in leaves with straight secondaries running direct to the margin, or breaking up there into reticulations, it serves as a character of some value.

The loops may be strong or weak, many or few, close beneath the margin or some distance in, and so on. Sometimes the tertiaries and veins of higher orders form series of superposed loops between the loops of the secondaries and the margin: in other cases the loops run so close to the margin, and are so slightly convex to it, that an infra-marginal vein running nearly parallel to the latter is formed by their union—e.g. Walnut (Fig. 17), and there is a tendency to something of the same kind in Clematis, Holly and Fig.

In the vast majority of cases the secondary ribs come off alternately in pinnate venation, e.g. Hornbeam, *Quercus Cerris*, Beech, Chestnut, though here and there a few may be opposite: it is rare to find them all opposite, though less uncommonly the basal pairs are so.

Characters of some value can be obtained from the average distances separating pairs of secondaries, expressed

when necessary in terms of fractions of the length of the midrib. For instance, they are distant in *Quercus Robur* and close in Oleander. The average distance apart, in fractions of the length of the midrib, is about $\frac{1}{5}$ in Birch, $\frac{1}{12}$ in Hornbeam, and $\frac{1}{25}$ in Oleander.

It is sometimes useful to characterise the shape of the leaf-area cut out by two successive secondaries, and bounded by them above and below, and by the midrib and margin (or loop, &c.) respectively to right and left: such an area is of course the first or principal mesh of the reticulation. It is approximately rectangular and straight in the Beech, Alder, Chestnut, &c.; curved in *Salix Caprea*, and so forth.

The tertiaries are the veins of distinctly finer calibre given off from both sides of the secondaries, and sometimes from primaries also, and which at once divide up the larger meshes into smaller reticulations: they are to be distinguished from the stronger branches of the secondaries already referred to, though it is not here worth while to attempt to distinguish them from the finer capillaries to which they give rise, and which end in the terminals.

The rule is that the tertiaries leave the secondaries at more acute angles on the outer than on the inner sides, but there are exceptions, especially in exotic plants. The tertiaries may be strong or weak in all degrees; long—e.g. Alder, Birch, or short—e.g. Elm, but they are almost always much shorter than the secondaries—e.g. Hornbeam. Though sometimes nearly equal—e.g. Elm, *Viburnum Lantana*—they usually vary much in length (Fig. 14).

Their course is usually curved—e.g. Elm, Birch, Beech, &c.—but not necessarily so, and in many leaves they run nearly straight and parallel across from one secondary to another, forming cross-ties—e.g. *Viburnum Lantana*—a very characteristic form (Fig. 14).

They may be opposite or alternate, or both mixed; many or few; distant or crowded, &c.—all characters of possible value in diagnosis.

The finer venation, as already said, I do not propose to distinguish in detail; but it is worth noting that the finer meshes of the reticulation, bounded by the tertiaries, &c., and in which the terminals end, differ sufficiently in form and size to be of some diagnostic value. They may be rounded-polygonal—e.g. Beech and Oak—or oval, linear, angular—e.g. *Salix cinerea*, &c.; the longer axis being oblique, horizontal or longitudinal in various cases. The visible meshes also vary much in size, though we need not refer to other than large or small; and the same refers to their distinctness—the network being conspicuous in *Salix Caprea* and *Berberis*, for instance, and inconspicuous in *Robinia*, &c.

From the application of such particulars as those treated above, it is found that various types and subtypes of simple, pinnate and palmate venations are to be observed in the leaves of our trees and shrubs. The principal of these may be summarised as follows. The student should note that all the broader leaves here concerned have reticulated venation, but great differences are observable according to the relative prominence of the primaries and secondaries, &c., and the relatively sudden or gradual breaking up into the network. Most of the following types depend on this and on the direction of the principal ribs.

In the simplest case a single primary rib only is visible, the midrib, and secondaries are either absent or are so small and buried in the tissues as to be invisible. It sometimes happens that a rudimentary network really exists, but so immersed in the leathery or succulent tissues that no signs are visible externally.

This may be termed *simple venation*, and when entirely hidden in the substance of the leaf we may term it *obscure* or *obsolete*. Examples are afforded by the following.

The venation is simple or obsolete, consisting of one rib (though there may be invisible cross-ties) or vein only, in

Tamarisk	Pines	Spruces
Firs	Larch	Cedars
Juniper	Yew	Cypresses
Thuja	Heather	Ling,

and it is more or less simple or obscure in the small leaves of

Broom	Mistletoe	Gorse
Sea Buckthorn	Petty Whin	Myrica.

The next case shows a single primary rib, the midrib, running from base to apex of the leaf or leaflet, and this gives off secondaries to right and left in pinnate order. These are straight, or nearly so, and run direct to the margin and end there, either without branching or putting forth fork-like branches all of which end direct in the margin; or they may again fork and the forks end there. In those cases where the secondaries run merely towards or near the margin, with no marked parallelism or straightness of course, the term *pinnate*, simply, may be applied; but in cases where the course of the secondaries is stiff and straight right up to the margin, and parallel one with another, we may conveniently use the term *strict-pinnate*. *Viburnum Lantana* (Fig. 14) affords a typical example of the former; and the Chestnut (Fig. 16) one of the latter.

The following also afford examples of *pinnate* venation:—

Laburnum	Blackberry	Raspberry
Rowan	Service Tree	Virginian Creeper
Aucuba	Wayfaring Tree	Box

Hawthorn	Oaks	Portugal Laurel
Cherry Laurel	Rhododendron	Azalea.

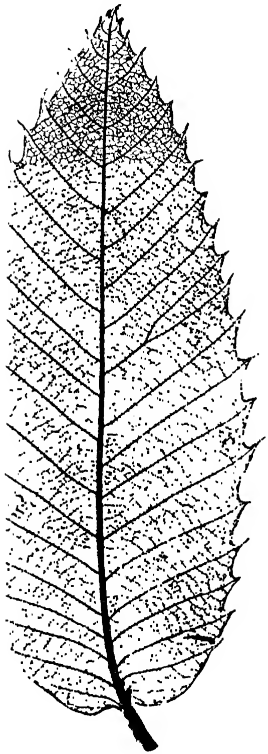

Fig. 16. Leaf of Chestnut, *Castanea vesca*, showing strict-pinnate venation. The tertiaries break up rapidly into the reticulation (Ett).

The following afford examples of *strict-pinnate* venation :—

Horse-chestnut	Chestnut	Hazel
Hornbeam	Elms	White Beam
Alder	Birch	Beech.

A third form of pinnate venation may be distinguished as follows. The single midrib gives off pinnate second-

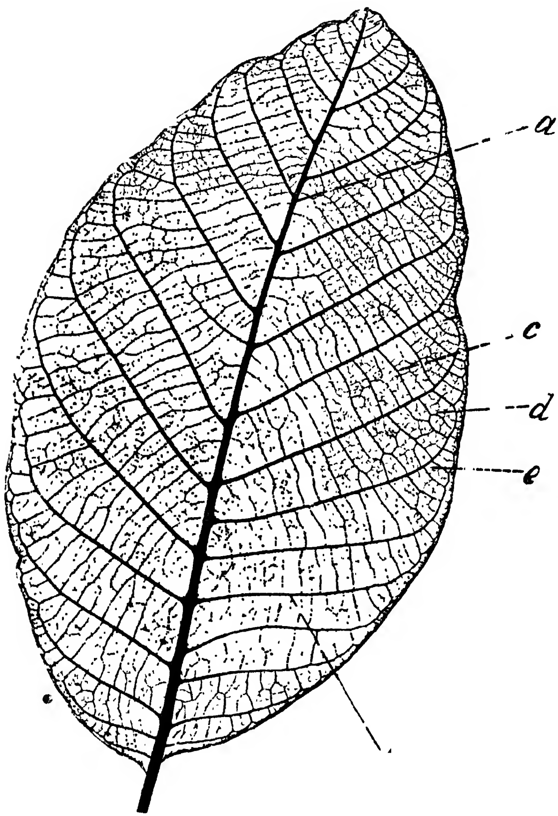

Fig. 17. Leaflet of Walnut, *Juglans regia*, showing pinnate-looped venation. The secondary ribs *b* leave the midrib *a* in pinnate order, but curve forwards (near *d* and *e*) and loop with the next in front. In this case the looping is so near the margin that an infra-marginal vein may result. *c* tertiaries, forming cross-ties and breaking up into the network (Ett).

aries, which do not end in the margin, but take a sinuous or curved, or more rarely straight, course, and then bend forwards at their tips and join in a loop, convex to the margin, with the next upward secondary (Fig. 17). We may term this *pinnate-looped* venation.

The following afford examples of *pinnate-looped* venation :—

Walnut	Traveller's Joy	Ailanthus
Robinia	Rose	Sweet-briar
Spindle Tree	Lilac	Holly
Apple	Blackthorn	Alder Buckthorn
Honeysuckle.		

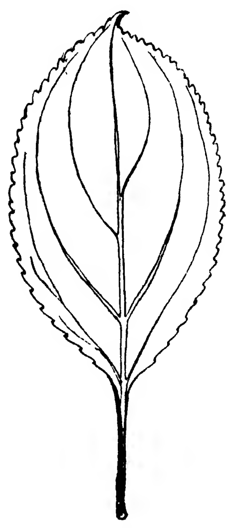

Fig. 18. Leaf of Buckthorn, *Rhamnus Catharticus*, showing pinnate-arcuate venation. The few pinnate secondary ribs curve forward and lose themselves in the reticulum near the apex (D).

In a fourth case, appropriately termed *pinnate-arcuate* venation, the single midrib gives off secondaries, which start in pinnate order, but curve forwards towards the apex of the leaf and there suddenly disappear in the network, without forming distinct loops or reaching the margins. The secondaries are typically much stronger than the tertiaries, and are few and distant.

The following are examples of *pinnate-arcuate* venation:—

Buckthorn	Dogwood.

In the following cases, which we may term *pinnate-reticulate* venation, the single midrib gives off pinnate secondaries at various angles and distances, but these soon break up into the general network, long before reaching the margin, and without forming distinct loops—e.g. Crack Willow (Fig. 19), and the following:—

Elder	Ash	Traveller's Joy
Robinia	Willows	Honeysuckles
Lilac	Privet	Holly
Apple	Blackthorn	Bullace
Plum	Gean	Cherry
Almond	Bird Cherry	Mezereon
Pear	Arbutus	Bittersweet.

In the following (Fig. 20), the venation is reticulate, breaking up so rapidly that although traces of its reference to the pinnate or palmate type exist, such type is not prominent:—

Barberry	Poplars	Mahonia
Daphne	Mulberry	Bittersweet
Pear	*Lycium*	Cotoneaster
Arbutus	Apple	*Vaccinium Myrtillus*
Lilac	*Salix reticulata*,	

and the following Willows:—

Salix fragilis	*S. pentandra*	*S. purpurea*
S. cinerea	*S. Caprea*	*S. reticulata*
S. repens	*S. viminalis*	*S. alba*
S. amygdalina	*S. nigricans*	*S. aurita.*

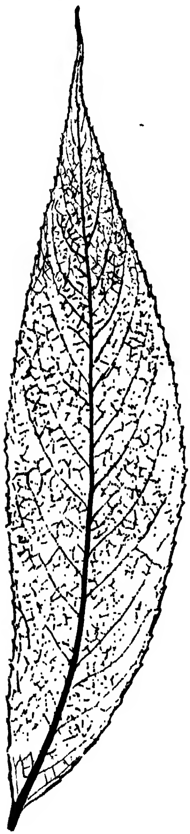

Fig. 19. Leaf of Crack Willow, *Salix fragilis*, showing pinnate-reticulate venation (Ett).

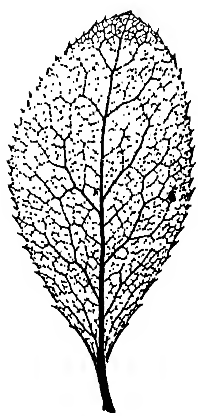

Fig. 20. Leaf of Barberry, *Berberis vulgaris*, showing reticulate venation (Ett).

The venation of the Willows has been investigated by Glatfelter, who states that, in spite of variations according

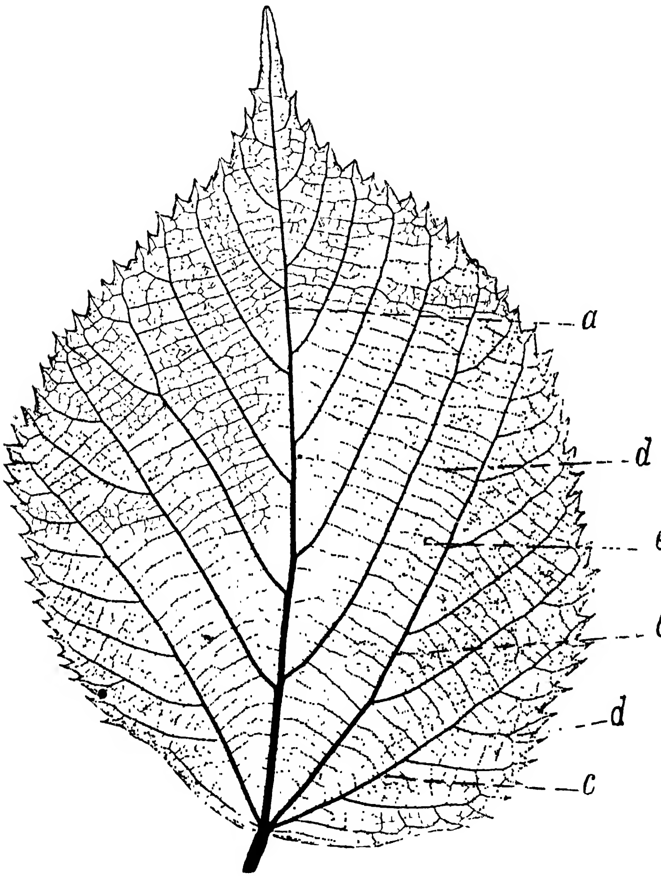

Fig. 21. Leaf of Lime, *Tilia europæa*, showing pinnate venation with pseudo-palmate base. The secondary ribs *b* and *c* at the base come off with the midrib *a* from a common origin: those higher up are pinnate. *d* tertiaries forming cross-ties; *e* network of terminals, &c. (Ett).

to the age of the leaf and the season, they can be grouped according to the characters of what we here term the tertiary veins. The secondary ribs of the pinnate venation run from the midrib nearly parallel to one another towards the margins. These give off the tertiaries, which may be parallel—curved or straight—or not; if the former he calls them regular, if the latter he calls them irregular.

The tertiaries are regular in *Salix alba* L., *S. fragilis* L. and *S. phylicifolia* L. They are irregular in *S. purpurea* L., *S. Babylonica* Tourn. and *S. herbacea* L.

I have however been unable to verify these conclusions, and doubt whether they can be upheld in the cases cited.

As with pinnate venation, so with palmate venation, several sub-types are recognisable when we pay attention to details.

Instructive cases, showing how readily the two types of pinnate and palmate venations merge one into the other, are afforded by the Lime and the Plane. In the former (Fig. 21) we see that while the predominant type is clearly pinnate, there are two or three basal secondaries which arise with the midrib at the base of the leaf and diverge at different angles, throwing out strong outer branches so that the venation of this leaf is almost palmate below. It may be appropriately described as pinnate with the base *pseudo-palmate.*

In the Plane, again (Fig. 22), while the venation appears obviously palmate at first sight, the two strong lateral ribs diverge from the midrib some little way above the junction with the petiole, and are, strictly speaking, merely the lower secondaries of a pinnate venation. Further examples of the same kind are to be met with in *Populus alba*, the Birch and elsewhere, and may be referred to as *pseudo-palmate.*

The following afford examples of *pseudo-palmate* venation :—

Guelder Rose	Ivy	Fig
Mulberry	Hawthorn	Plane.

Fig. 22. Leaf of Plane, *Platanus orientalis*, showing pseudo-palmate venation. If compared with the Norway Maple (Fig. 15) it will be seen that the basal primaries do not originate strictly from the same point with the midrib (Ett).

The following afford examples of *pinnate* venation with pseudo-palmate base :—

Traveller's Joy	Service Tree	Abele
Grey Poplar	Hawthorn	Ivy
Lime	Aspen	Black Poplar.

In typically palmate venation all the principal ribs behave as primaries and must be regarded as such. These primaries arise, together with the midrib, from one point at the base of the leaf where it joins the petiole, and diverge thence in a radiating manner, as is well seen in the Norway Maple (Fig. 15).

The following afford good examples of true palmate venation :—

Maple	Sycamore	Norway Maple
Black Currant	Ivy	Gooseberry
Vine	Red Currant	Fig.

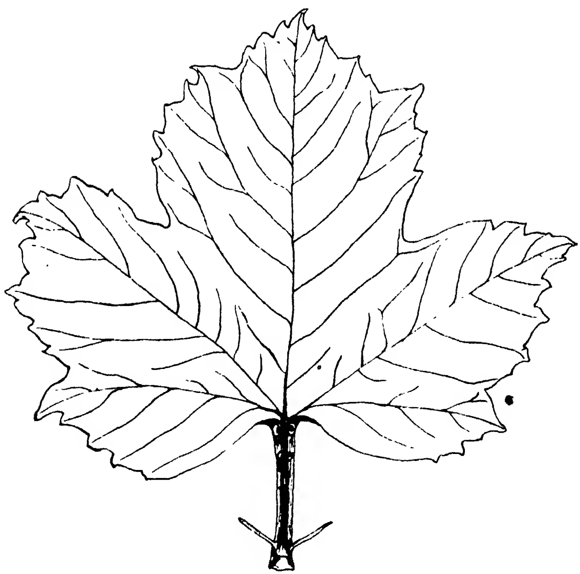

Fig. 23. Leaf of Guelder Rose, *Viburnum Opulus*, showing palmate-pinnate venation (D).

Two varieties of the palmate type stand out when we

come to examine the behaviour of the secondaries, thrown off from the various primary ribs.

In the one, we find three or more primary ribs enter the margin from the petiole, of which the central one runs forward to the apex as the midrib and ends in the tip, while the lateral primaries radiate in diverging lines, running to the tips of the lobes and acting, so to speak, as subsidiary midribs, one to each lobe. Each of these primaries gives off secondaries in pinnate order, which in their turn run to the margins, and either end there, or loop, or break up in different cases; e.g. *Viburnum Opulus* (Fig. 23). This form may be termed *palmate-pinnate.*

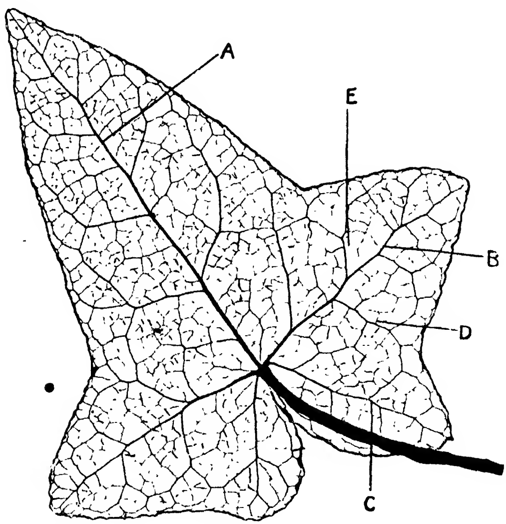

Fig. 24. Leaf of Ivy, *Hedera Helix*, showing palmate-reticulate venation. *A* midrib; *B* and *C* lateral and basal primaries; *D* and *E* network of secondaries, tertiaries, &c. (Ett).

In the other case, the radiating primary ribs diverge

from the petiole, but only the midrib, and perhaps the lateral primaries nearest to it in their course, reach the tips of the lobes or the margin; the outer or basal laterals take a sinuous course and branch or dichotomise before reaching the margin, and then break up in various ways, e.g. Ivy (Fig. 24). This variety is aptly described as *palmate-reticulate*.

It is not always possible to refer the venation of a leaf to any single one of the above types, and we then have recourse to compounds of two or more, or we have to refer approximately to one or other of the types.

CHAPTER VI.

CELLS AND CELLULAR STRUCTURE.

Different kinds of cells—Cell-cavity, cell-wall, cell-contents—Tissues—Intercellular spaces, and middle lamella—Gas interchange—Cell-tissues due to division and partitioning: not to juxtaposition—Various connotations of the word "cell"—The typical cell—Embryonic cell—Protoplasm, cytoplasm—Nucleus—Plastids—Chlorophyll-corpuscles—Vacuole—Thickening of cell-wall—Vessels.

It is impossible in a work of this kind to carry our studies far into those regions of minute structure which demand the use of the microscope, but so many phenomena depend on the properties of the cell, that the following sketch of the subject of cellular structure may be useful to the reader.

If we cut a very thin slice through any piece of plant-structure, such as elder-pith, cork, or wood, or through a seed like that of the Bean, or a fruit such as an Apple or a Cucumber, or any ordinary leaf, a root of, say the Carrot, or a tuber such as the Potato—in short, through any part of a plant, it is possible to show by means of the microscope that the substance of the section is not homogeneous, but is more or less distinctly chambered. The cavities of the chambers are either empty of all but air or water, or filled with various matters

to be described later; and the walls of the chambers consist of some solid substance and present various degrees of thickness in different cases.

These chambers are known as cells, owing to their more or less obvious resemblances to the well-known cells of honeycomb, a fact which suggested the name to Hooke, who applied it in 1667.

At the very outset the student who observes and compares such objects as have been named will find differences of the following kinds.

In some the cell-chambers are large, and visible even with a simple lens—e.g. pith, wood, &c.; whereas in other cases they are small and require the compound microscope for adequate examination—e.g. cork, leaf-tissue, Bean, &c. Again, the cork, pith, and wood show for the most part empty cavities—i.e. the cells are filled with air only; whereas in the sections of the Bean, Apple, Cucumber, Carrot, and Potato, or the leaf, most of the chambers evidently contain something other than air, such as watery fluid or various solid objects. Further, the partition-walls which separate the chambers (cells) one from another differ considerably in thickness and distinctness in the various cases—e.g. they are very thin in the slices of apple and potato, or of leaf-tissue, and much more evident in the wood; the shapes of the chambers also differ, by no means preserving the regular hexagonal shapes of the cells of honeycomb.

From the above considerations the student will now understand the following. The cavity of each cell is termed the *cell-cavity*, the partition-walls are the *cell-walls*, and the contents are spoken of as *cell-contents.*

If we extend this preliminary examination of cell-structure to sections carefully cut in definite directions across the various organs of plants—e.g. transverse to, or

parallel to the longitudinal axis of stems, roots, leaves, fruits, tendrils, &c.—two further general conclusions are forced upon us.

In the first place we discover that different kinds of cells, in the sense referred to above, occur in one and the same organ, as well as in different organs of the plant; and, secondly, that the various cells show more or less definite grouping or arrangement with reference to the centre or axis and the planes cutting this in the section. In many cases, in fact, these groupings result in the formation of beautifully symmetrical patterns.

These sections also teach us still more clearly that the cells are closed box-like chambers, of various shapes and sizes, with walls differing in thickness and in other respects, and enclosing very different cell-contents in the different cases.

The groups of cells which stand out on such sections are called *tissues*, owing to the suggestion on the part of earlier observers that some of the groups are woven into and between others. The original idea was a mistaken one, but the name has persisted, and will be used with a totally different connotation, implying, as we shall see, little beyond the truth that a tissue is a co-ordinated group of cells more or less similar in behaviour and appearance, and differing in these respects from other groups (or tissues) which have their own peculiarities. To some of these matters I shall return: meanwhile it is necessary to examine a few further peculiarities concerning the cell-structure of plants.

Even the resistance which the razor meets with as it passes through the plant-organ convinces us that the network of cell-walls is more solid and continuous in some cases than in others; and the microscope shows that while in some cases the cell-walls are quite continuous, in others

there are gaps in the corners where three or more cell-partitions converge. In other words, the cells have partially separated here, as if partly torn asunder. The separation may be found to have been carried to a much further extent in leaves, where the cells are only left contiguous along relatively narrow surfaces.

These lacunæ between the cells are called *intercellular spaces*, and are formed by the partial separation of cells, the common walls of which were previously in complete continuity. This separation occurs by the splitting of the common partition-walls, along the boundary-plane which theoretically separates what belongs to one cell from what belongs to the other; and in the thicker cell-walls of sections we can see a distinct bright line running midway between the cells, in which the transverse section of the plane referred to must lie. This line is called the *middle lamella*, and it is in fact the dissolution of this middle lamella which determines the separation of the cells.

The degree of separation varies in different cases from almost nothing to complete isolation of the cells. In cork and usually in wood, for instance, we find no intercellular spaces at all developed, or only very minute ones here and there: they are small and usually triangular in section in the soft tissues of seeds, fruits, stems, roots, &c.; while in leaves, the pith of some rushes, the softer tissues of many marsh and aquatic plants (e.g. *Myriophyllum*, *Œnanthe*, *Butomus*, &c.) whole series of cells become nearly completely separated, the *intercellular spaces* being often larger than the cell-cavities, and in some cases very much larger (e.g. Aroids, Musaceæ, Water Lilies, &c., where they are visible to the unaided eye).

In all these cases the advantage of the spaces is to allow gases, especially air, to obtain access to the cells,

or to facilitate the escape of such gases or water vapour from the cells to the exterior; though they are often utilised by the way as reservoirs in which air may collect for the time being and float the organs on water—e.g. *Pistia*, *Pontederia*, *Trapa*, &c.

The separation of cells is often carried to complete isolation, however, as in the formation of spores, pollen-grains, and in other cases. The fine dust of minute spores which escapes from a puff-ball, a moss-capsule, and the yellow powdery pollen from the anthers of Lilies and other flowers are all separated cells which have thus been isolated from a continuous cell-tissue by the dissolution of the middle lamella, and in a vast number of the lower plants—Algæ, Fungi, and Bacteria—the whole plant-structure thus breaks up into single cells, and during a great part of the life of the organism the latter consists of a single isolated cell only. We shall see, moreover, that many contrivances in plants depend on the partial or complete separation of the cells by the splitting of the middle lamella. That this splitting of the middle lamella is really due to its more or less extensive dissolution, is borne out by experiments wherein it is artificially dissolved. When a potato, apple, turnip or other soft organ is boiled, the cells are isolated owing to the action of the hot water on the middle lamella, a process very similar to what occurs naturally when fruits like the Tomato, Peaches, and Grapes, &c. ripen to a pulpy mass of isolated cells. Similar isolations occur in the alimentary canal of every school-boy who eats, and successfully digests, an unripe apple or pear; or of a horse, cow, sheep or other herbivorous animal which eats grass or other leaves, grain, &c., and cells thus separated under the action of the intestinal fluids occur in the excrement of all herbivorous animals. In wood and other resistant

tissues it is possible to separate the elements at once by the action of strong oxidising reagents—e.g. nitric acid to which chlorate of potassium is added—and the same event is brought about more slowly by exposure to the weather, as in rotting. Many fungi are also known which creep in and feed upon the middle lamella, excreting solvent enzymes which dissolve its substance: in these cases we see an excellent justification for the views given, for such fungi act in a certain sense like instruments which are passed into the plane referred to above and part the cells asunder.

The importance of the above discussion to the student is to put him on his guard against any such view of cell-structure as might lead to the implication that individual cell-chambers have been brought into juxtaposition from a state of isolation: the facts are exactly the converse. The true cell-structure of an organ or plant is really a whole, chambered up into cells by the repeated interposition of partition-walls, and we might compare it to the building of a house, if we could suppose the rooms to expand and new partition-walls to be inserted across them. What we must *not* compare it to is a building made up of separate box-like compartments brought into juxtaposition.

It is true that in certain specific cases fusions may occur later, by which the common wall between two cells becomes broken through, and the cavities thus brought into open connection, and it is by this means that longitudinal rows of cells become joined into continuous pipes or tubes called *vessels*; but the point to be emphasized here is that the wall between any two cells is primarily *common to both of them.*

The word "cell" has been used to mean very different ideas at different periods in the history of botany. When

Hooke applied it in 1667 he meant, as we have seen, the empty cavities in the framework of cell-walls, and so the word signified a mere cavity. Later on it was, and still is, applied to the cell-wall, together with its living cell-contents, forming a whole bounded by the ideal plane which separates one cell from the other; and finally (in part owing to the influence of zoology, because in animal cells the cell-wall is usually not prominent) the word has been applied to the living cell-contents alone, which are not unfrequently met with, even in plants, as naked individuals which have escaped from the cell-wall. Since, however, the empty dead cell-frameworks were at one time filled with living contents, we now recognise that they are not complete cells, but the skeletons which have been left behind when the contents disappeared; and, similarly, since we now know that the naked individuals without cell-walls, sooner or later acquire the protective covering, the modern idea of the cell is easily grasped and shown to include all the others. Since, however, the cells in different parts of plants and in different species undergo enormously varied changes both in the contents and the cell-walls, we must fix our ideas a little by selecting a typical cell for reference.

Such a cell may be found in the earliest stage of every plant, and is the only constituent of many of the lower plants, the cells of many Algæ, Fungi, &c. never advancing beyond this primitive condition, and since we find such cells again in the youngest stages of all new organs—e.g. in the growing-points, roots and stems, leaves, flowers, &c., of Mosses, Ferns, and flowering plants—we are justified in taking it as the type.

The most convenient example is obtained from a section through a growing-point of any young organ of a higher plant.

We have here a number of more or less cuboidal or polygonal cells, each of which is bounded by a thin *cell-wall*, and is densely filled with granular, semi-translucent contents in which several kinds of enclosures occur. The contents consist of living *protoplasm* and its enclosures, and since this particular mass of protoplasm constitutes the contents of a cell, we call it the cell-protoplasm, or, more shortly, the *Cytoplasm.*

Embedded in the cytoplasm are several objects. Some of these are mere granules or delicate fibrils to all appearance, while others are much more conspicuous and complex living bodies, which since they *never occur outside living protoplasm* we must regard as organised parts—i.e. small organs or organites—of the cytoplasm.

The most conspicuous of these is a large rounded body called the *Nucleus*: it also consists of a kind of protoplasm and has granules and fibrils in it, and is sharply marked off from the cytoplasm by a definite boundary. It also contains a dense bright rounded mass known as the *Nucleolus.*

In the cytoplasm, but outside the nucleus, are several more or less rounded colourless bodies termed *Plastidia*, or, shortly, plastids; and in some cases the best observations show a number of other minute granule-like structures lying either in the nucleus, or in the cytoplasm, the most important of which are the brilliant green bodies, especially abundant in leaves, called *Chlorophyll-corpuscles.*

One of the most important of all the important generalisations of the biology of the last twenty-five years has been to show that, as regards essential features, the constitution of a typical animal cell is like that of a typical vegetable cell: there also zoologists have

found that we have a cell-wall enclosing protoplasm, and this protoplasm comprises a granular and fibrillated cytoplasm enclosing a nucleus with its nucleolus and other bodies, the principal difference being that in animal cells the cell-wall is not usually a prominent feature.

Even in vegetable cells the student must not assume that all the organs of the protoplasm are always present in the complete form described. Many cells do not show the plastids, though that is probably in some cases because they are so minute as to be hidden among the granules of the cytoplasm.

Still more frequently—e.g. all Bacteria and Fungi, parasitic plants and the non-green parts of other plants—chlorophyll-corpuscles are not seen; while in a few cases (becoming fewer, however, each year as improved methods of observation are invented and applied) the nucleus seems to be absent, probably because the nuclear matter is not brought together in the form of a definite organ, but remains scattered in the cytoplasm.

There are two other points to be considered, moreover, before our ideas of the cell are brought into accord with the teachings of modern botany.

Turning to the embryonic cell described above we notice that its cell-wall is extremely *thin*, and that its protoplasmic contents *completely fill* the cavity.

As this cell gets older we find two events of primary importance happening.

The first is that minute drops of watery liquid gradually appear in the cytoplasm of the growing cell, and grow larger and larger until they occupy more space than the whole of the rest of the contents. These spherical drops are called *Vacuoles*, a name given at a time when, owing to their clear appearance the spheres were thought to be

empty spaces: the liquid they contain is called *Cell-sap.* As the vacuoles increase they coalesce and drive the protoplasm to the side-walls of the cell, the volume of which increases at the same time, until at length there is one large vacuole occupying by far the greater portion of the cavity, surrounded by the cytoplasm, now thinned out to a mere lining on the cell-wall, in which lining the nucleus, chlorophyll-corpuscles, plastids, &c. still lie.

The second event is that the cell-wall becomes thickened by additions on its inside during this enlargement; this means that new substance has been added to it, and the important point for the moment is that the substance of the cell-wall *comes from the protoplasm,* and has been made by it.

If we follow the fate of such a cell as the above still further we may find that as the cell-wall becomes thicker, the protoplasmic contents and cell-sap disappear altogether, and nothing but an empty cell-cavity surrounded by its cell-wall remains—i.e. a cell in Hooke's sense filled with air. This is evidently not a complete cell, but only the skeleton of cell-wall.

The proof that the cell-wall is formed by the protoplasm is direct; for not only does every plant known originate from a spheroidal mass of protoplasm which is for a longer or shorter period devoid of a cell-wall, and surrounds itself with one later, but in many Algæ and Fungi, as well as in other plants, the protoplasm escapes from certain of the cells, and lives an independent existence for a longer or shorter period, eventually clothing itself with a cell-wall, the substance of which can only have been formed and secreted by the protoplasm. This occurs, for instance, with the zoospores of Algæ and many Fungi, and the Myxamœbæ of the Myxomycetes. In the case of the antherozoids of many Algæ and Mosses, Ferns

and other vascular Cryptogams, indeed, the escaped protoplasmic contents do not clothe themselves, but die if they do not reach their destination, the protoplasm of another naked cell.

The student is now in a position to apprehend generally the meanings which have been attached to the word "cell" in its various vicissitudes in the history of Botany. Originally applied by Hooke with its ordinary signification to the cell-cavity with its boundary wall only, it came to connote the cell-wall plus its protoplasmic and other contents, and finally was extended to signify the living protoplasm only.

Now, since the protoplasm is the essential part of the cell, and may produce all the other parts, we may term such a naked cell as a zoospore, oosphere, antherozoid, Myxamœba, &c. a *Primordial cell.* Then in cases where the primordial cell has clothed itself with a thin cell-wall and is in train to become vacuolated and develope further, we may speak of an *Embryonic cell.* When the cell-wall and vacuoles exist in their typical form, and the protoplasm shows itself differentiated into cytoplasm, nucleus, chlorophyll-corpuscles and plastidia, and other typical cell-contents, we have the *Typical cell*; and, finally, in those cases where the cell-wall alone is left, the term *Cell-chamber* may be employed. This leaves us free to use the word "cell" in its perfectly general sense, as is so commonly done, and the various kinds of cells can then be dealt with, and special names given to them as occasion demands. The term *Cell-tissue* then means merely a group of cells, without prejudice as to the kinds of cells meant: the various kinds of cell-tissues will receive their special names according to peculiarities to be recognised later.

It merely remains to add, for the general purposes of

this preliminary sketch of the nature of cells, that in definite situations in the tissues of the higher plants—with which alone we are here concerned—long series of cells become converted into thin capillary tubes or pipes, called vessels, by the perforation of their separating walls so that their cavities become continuous end to end; by the thickening of their cell-walls to give rigidity to the side-walls of these pipes and so enable them to withstand pressures and strains of various kinds; and by changes in their contents, often resulting in the entire disappearance of the protoplasm, nucleus, &c., so that their cavities fill with water and gases of various kinds, or with liquids of special nature in different cases. We are not here concerned with the details of structure, size, or the many peculiarities of marking on these vessels; it is sufficient for our present purpose that these pipes convey fluids more or less rapidly from place to place in the stem, roots, leaves and other organs, to and from the cells in which such fluids are used or prepared, and in which they could only move slowly by diffusion through the separating cell-walls.

CHAPTER VII.

THE STRUCTURE OF THE LEAF.

The leaf a machine—Compared to an umbrella—Ribs and vessels compared to girders and water-pipes—Leaf-skeletons—Epidermis—Vascular system—Mesophyll—Continuity of tissues of like kind.

As already stated, it is not within the scope of the present work to enter into the details of the anatomy and microscopic structure of leaves, but since it will be necessary to say something of the principal functions of these important organs, and since it would be impossible to understand the actions and reactions which go on inside them, without reference to the leading features of their internal structure, it will be necessary to have a sketch at least of the machinery concerned.

For the leaf is, in effect, a complex piece of machinery, the working of which may be compared generally with that of many engines, though no artificial structure compares with it in efficiency or delicacy of action, and the comparison must always be understood with that qualification.

It has already been pointed out that the ordinary green foliage-leaf is essentially a thin lamina of soft tissue stretched on a framework of supporting fibres, much, in

effect, as the silk of an umbrella is extended on its supporting framework of steel ribs; and that the petiole may be compared to the handle and stick of the umbrella which lifts the expanded tissue up into the light and air. It has also been shown that the supporting network of fibrous structures is accompanied by a series of afferent pipes which conduct water from the roots to every part of the leaf, and which we compared to the water-supply of a town, and by a similar series of efferent pipes which convey other fluids in the reverse direction. This latter system reminds us in its distribution of the drainage-system of the town, only, as was pointed out, the materials gathered up into it from all parts of the leaf, and conveyed by it into the plant are very different from the waste-products poured into the sewers: they are, on the contrary, the nutritious food-materials on which the rest of the living parts of the plant are to be fed.

Nevertheless, in its broad features the analogy holds, and we may conclude that the afferent system of pipes conveying the water brought up from the roots, and containing traces of salts such as chlorides, sulphates, phosphates and nitrates of magnesium, calcium, sodium and potassium, which must inevitably be dissolved in such soil-water, as well as the efferent system of pipes conveying very different solutions away from the leaf to places where they are wanted for nutrition in the plant, simply accompany the supporting framework as a matter of economy and adaptation.

The network of pipes and fibres referred to is easily rendered conspicuous by any of the processes used for obtaining the so-called skeleton of a leaf, the commonest of which is the natural one of allowing the leaf to lie in stagnant water until the process of rotting has gone so far that the softer tissues of the leaf are reduced to pulp

and may then be readily washed away from the supporting network. But in practice it is usually found that the removal of this rotted pulp is for a long time obstructed by a thin transparent skin continuous over the whole of both surfaces of the leaf, and which contains within it, as in a flattened bag, both pulp and network. Sooner or later, however, this skin also rots and with the pulp can easily be removed from the more resistant network by gentle brushing with a camel's hair pencil under a stream of water.

The enveloping skin of the leaf is the *Epidermis*: the network of pipes and fibrous strands is the fibro-vascular system or venation, and will here be called the *Vascular system*: the pulp between, which in the fresh living leaf forms the green tissue of the lamina, is termed the *Mesophyll*.

It is not necessary here to carry far either of the two following amplifications of our subject, because my purpose is neither to describe in detail all the structural variations to be met with in the leaves of different plants, nor to enter upon discussions of theoretical morphology: the first amplification must here be satisfied by the statement that in many leaves the vascular system does not form copious networks of the kind here referred to, while in others the quantity of fibrous supporting tissue may be much greater or less than that met with in the common typical leaf—such as that of the Beech, Oak, Lime, Maple, Poplar, Elder, Lilac, Gooseberry, &c.—here concerned.

The second amplification must be satisfied by the statement that no useful purpose would be served here by trying to classify the tissues or structures I have called Epidermis, Vascular system, and Mesophyll into different groups, such as would have to be done were we concerned with recondite questions of histology and morphology.

A point which is of importance to us here, however, is the following. Each of the structural systems above referred to is continuous with its like in the stem, root and other parts of the plant. The epidermis of the leaf stretches over not only the whole surface of the lamina and petiole, but is absolutely continuous as epidermis over the shoot which bears the leaf. The vascular system not only pervades the whole leaf-area, but is continued down the petiole and joined on to the similar vascular system running throughout the shoot and root and into every branch, bud, tendril, flower, &c., which it puts forth. In like manner the soft mesophyll which fills up all the intervals between the vascular system (venation) of the leaf and its epidermis, is continuous through the petiole with the same kind of intervening soft tissues between the epidermis and the vascular system of the shoot, and, by its continuity with this, is continuous with the corresponding tissues in every root, branch, flower, &c., throughout the plant.

This continuity of the tissues of like kind throughout the plant is a matter of the utmost importance. Any one of the systems may undergo rupture and destruction subsequently, in the older stems, roots, &c., but it is primarily absolutely continuous throughout, and, similarly, it never joins another system, though it may abut closely on to it; each system is sharply marked off from the other from first to last. See Fig. 56 and pp. 102—105 in Vol. I.

After this introductory survey, we may now examine each of the three systems somewhat more closely.

CHAPTER VIII.

THE VASCULAR SYSTEM AND VENATION.

Terminals end blindly in the mesophyll—Exchanges of water and food-substances—"Circulation of sap"—Afferent and efferent pipes—Source of carbon.

On examining a very thin leaf, such as that of a Bilberry, Lilac or Honeysuckle, or *Salix herbacea*, under a good lens or a low power of the microscope, especially if the leaf be first heated in water and all the entangled air driven out, it will be seen that the ultimate branches of the vascular network—i.e. the smallest veins or terminals—end blindly in the mesophyll, tailing off as they do so into two or three, or even a single pipe or vessel or similar structure. The blind end abuts closely on to one or more delicate bags, or cells, and so comes at its end and sides into direct contact with the mesophyll, which is composed of innumerable thousands of such bladder-like bags or vesicles (cells).

It is at these blind ends, which are to be found in hundreds and thousands all over the leaf-area, that the exchanges of fluids between the mesophyll and the vascular system take place. Whenever the vascular pipes are full of water—and by water we are always to understand water with traces of minerals dissolved in it, like ordinary drinking water—while the cells on which they abut are for any reason short of water, then such water

passes from the pipes to the cells at these points of contact, diffusing through the membrane separating the cavity of the cell from that of the pipe.

If, on the other hand, the mesophyll-cells contain a surplus of water—and such water will have dissolved in it traces of bodies like sugars and other nutritious substances which, as we shall see later on, are produced in the cells—while the vascular pipe ends are lacking in such water, then passage will occur through the separating membranes from the cells to the vascular system.

But it is a significant fact that the vascular pipes which deliver the water to the mesophyll-cells are not the same as those which collect from the latter; though both sets of pipes lie close together at the blind ends of the veins. Whence we see that the terminals deliver to the mesophyll-cells, by way of one of their double sets of pipes, water containing traces of dissolved salts that have been brought up the stem from the roots, which absorbed them from the soil; while they collect from such mesophyll-cells water containing food-materials such as sugars, &c., dissolved in it, and pass this on by the second of their double sets of pipes, into the larger veins and ribs of the venation. Thence the solutions pass down through the petiole into other parts of the plant, where the sugars, &c., are used as food-materials to build up the structures of new buds, flowers, roots, &c., as required.

It will now be understood why we cannot speak of the above as a "circulation of sap"; for it is not the same liquid which was brought up by the afferent pipes of the venation that returns by the efferent flow in the other pipes. The former is water with traces of mineral salts dissolved in it: the latter is water with organic substances, such as sugar, and other bodies containing carbon in the molecules, dissolved in it. We know of

no mechanism or agency which can convert minerals like the salts of calcium, magnesium and potassium, &c., above referred to, into bodies like sugar, starch and acids, &c., which contain carbon in their molecular structure; and even if we did the relative weights of the solid substances dissolved in the collected liquids are so much greater than those of the traces of minerals in the water delivered by the vessels to the mesophyll-cells, that even if minute traces of some carbon-compound did exist in the latter, the fact would not enable us to escape from the following conclusion.

Somewhere and somehow the mesophyll-cells must have added the sugar or other carbon-compounds to the efferent liquid. They must have taken the water from the afferent pipes, and possibly made some use of the traces of minerals therein, but they must have added the sugar or other carbon-compound to the water collected from these pipes. They cannot possibly have converted any part of the water or minerals into carbon, and the question therefore resolves itself into, Whence did the mesophyll-cells obtain the carbon necessary to explain the presence of such relatively large quantities of carbonaceous bodies, such as sugars, delivered up to the efferent system? Only one source of this carbon is possible—viz. the carbon which always exists in the surrounding atmosphere, and we shall see later on that we now know that that *is* the source: the chlorophyll-corpuscles absorb carbon-dioxide from the air, tear the carbon from it, and build it up with oxygen and hydrogen into the sugars, &c., in question.

Before we can understand this, however, it is necessary to examine the other tissues of the leaf somewhat more closely.

CHAPTER IX.

THE MESOPHYLL.

Spongy mesophyll and palisade cells—Transverse section of leaf—Mesophyll-cell—Intercellular spaces and gas-interchanges—Stomata—The intercellular labyrinth—Phenomena to be met with in the labyrinthine tunnels—Day and night changes—Chlorophyll-corpuscles—Protoplasm and other cell-contents—Functions of chlorophyll-corpuscles—Starch—Photo-synthesis, or carbon-dioxide assimilation.

THE mesophyll forms a sort of spongy filling-up tissue between the epidermis and the vascular system, as we have seen, and the green colour of the leaf is entirely due to the countless millions of minute brilliant green bodies contained in the mesophyll-cells, and called chlorophyll-corpuscles.

The spongy soft feel of the mesophyll is due to the fact that the cells are throughout the greater part of the mesophyll not closely in contact on all sides, but have relatively large or small intercellular spaces separating them one from the other except at certain points where they abut on their neighbours, or on the vascular bundles of the venation, or on the epidermis.

Were it not for these intervening spaces, which contain only gases and vapour, the fresh leaf would be quite hard and elastic to the feel, because each mesophyll-cell is a

vesicle, like a bladder, tensely distended by the water it contains, and a closely packed system of such distended bladders would be very rigid.

There are differences, however, in the relative rigidity of the upper and lower parts of the mesophyll of one and the same leaf, and also of the mesophyll at different periods; the former being due to differences in the relative volumes of the interspaces between the cells nearest the upper or the lower surfaces respectively of the leaf —or, what is the same thing, differences in the closeness of the packing of the cells—while the latter is due to the quantity of water at the disposal of the mesophyll-cells.

Everyone knows that if a soft thin leaf, like that of a Lilac or Elder, is plucked from the plant and carried in the hot hand, its fresh and rigid condition soon gives place to a state known as drooping: the leaf becomes limp and flaccid because water has been evaporating from the cells, and they collapse from their previously distended or turgid condition, as may be seen under the microscope. The loss of water may readily be observed by placing such a fresh leaf on a balance and carefully equipoising it: the scale containing the leaf soon rises, because the cells lose water, and since we have torn the leaf from the stem—broken the water pipes—no more can flow in to replace that which is lost.

The arrangement of the mesophyll-cells is best seen in a section of a leaf such as that shown in Fig. 25.

Neglecting for the moment the epidermis (*b* and *d*) which surrounds the whole section, and the cut vascular bundles (*a*, *c* and *e*) which run through the mesophyll, we see that the mesophyll in the upper moiety of the section consists of cylindroidal cells standing vertically, and so closely in contact with each other at the sides, and with the epidermis at their upper ends, that the intercellular

spaces between them are quite inconsiderable. The peculiar shapes and arrangement of these cells suggested

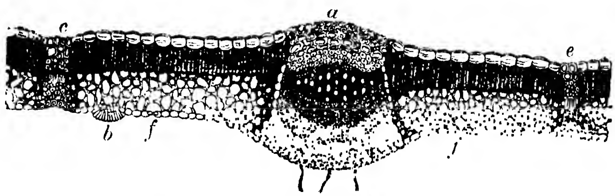

Fig. 25. Transverse section across a leaf of the Birch, *Betula alba*, in the region of the midrib *a*, and passing through two smaller ribs *c* and *e*; *d* upper epidermis, beneath which is the palisade-layer; *b* gland on lower epidermis; *f* stoma leading through the lower epidermis into the intercellular spaces of the spongy mesophyll (Ha).

the name "palisade" for them, and botanists generally speak of this layer of the mesophyll as the *palisade-tissue* or layer (Fig. 26).

Now let us observe how different is the state of affairs

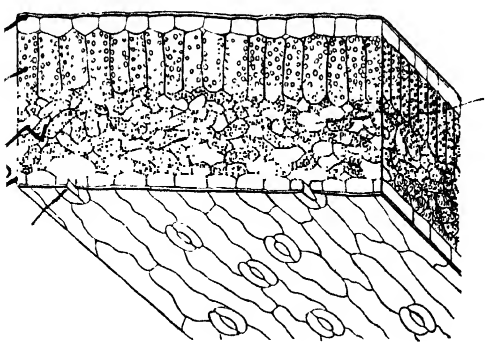

Fig. 26. Semi-diagrammatic view of a leaf in section, showing upper and lower epidermis, the latter with stomata. Between these two layers the mesophyll, the palisade-tissue above, and the spongy tissue below. Two stomata in section show how the intercellular spaces communicate with the external air (G).

in the lower moiety of the section. Here the cells themselves are irregular in shape, and only in close contact one with the other, or with the epidermis of the lower surface of the leaf, by relatively small parts of their surfaces: they have been driven apart by the formation of large cavities, or *intercellular spaces*, as they are called, so that the whole tissue presents a close resemblance to a sponge, and so this portion of the mesophyll is termed the *spongy tissue* (Fig. 26).

The leaves of all our common trees and shrubs, such as Clematis, Barberry, Lime, Horse-chestnut, Maples, Dogwood, *Rhamnus*, Robinia, Laburnum, *Prunus*, *Pyrus*, Roses and Brambles, *Ribes*, Honeysuckles, Ash, Elms, Alder, Birch, Hornbeam, Hazel, Walnut, Plane, Beech, Oaks, Poplars and Willows, agree in every essential of structure with the typical case here described; and although there are differences in the details of arrangement in the narrower and more rigid leaves of the Conifers —Pines, Firs, Yew, Larch, Cedars, Juniper, &c.—the same principles are recognisable in these cases also.

Moreover, the essential features are also similar regarding the points now to be described.

Each mesophyll-cell is a delicate vesicle separated from its neighbours, or from any other cell or vessel on which it abuts, by an extremely thin cell-wall or membrane, easily permeable by water. Similarly where the cell-membrane abuts on any of the intercellular spaces, its thinness and permeability allow of ready passage of water from cell to intercellular space, or from intercellular space to cell. But the intercellular spaces rarely contain liquid water, though they may occasionally do so. In the normal state of affairs we find them filled with gases and water-vapour only, and the results of thousands of observations and experiments show that the gases are almost

entirely those of atmospheric air, viz. carbon-dioxide, oxygen, and water-vapour in various proportions according to very complex and varying conditions, among the principal of which are the hygrometric and barometric condition of the atmosphere, the life-activities of the cells, the amount of water in the plant, the temperature, and the illumination to which the leaf is exposed, together with certain controlling effects to be discussed later in connection with the epidermis.

The point to be here emphasized is that the mesophyll-cells are continually, during the whole life of the leaf, giving off into, and taking up from the intercellular spaces water-vapour, oxygen, and carbon-dioxide in all sorts of proportions according to circumstances; for each living mesophyll-cell must have oxygen to enable its protoplasm to respire, and it gets this oxygen from the air which has diffused into the intercellular spaces from the outside atmosphere; again, each living mesophyll-cell must get rid of most of the water passed into it from the vessels, as otherwise it cannot make room for more water, and would then be deficient in the necessary salts of potassium, calcium, &c., brought to it in such minute quantities dissolved in the water; finally, each living mesophyll-cell must have supplied to it quantities of gaseous carbon-dioxide in order that the materials for the work of the chlorophyll-corpuscles—which are the machines in which the carbonaceous materials are manufactured—may be secured.

All these gas and vapour interchanges from cell to intercellular space and from intercellular space to cell, varying in rapidity and amount at different periods as they do, are controlled in many ways; and they must all take place through the moist cell-wall and its living lining of protoplasm.

The interchange is also facilitated by the continuity of the system of intercellular spaces, not only throughout the leaf, but throughout the whole plant, and with the external world by means of the apertures in the epidermis, known as stomata (Fig. 26) and to be described shortly.

Let us imagine, for the sake of illustration, that there existed some minute intelligent being, with sufficient activity to wander through the enormous labyrinths of intercellular passages, and try to figure to ourselves what experiences he would encounter. He must be supposed to be small enough to enter one of the stomatal apertures, and able to wander about freely in the intercellular passages (see Fig. 26), and to have all his senses attuned to the minute scale of his environment. The kind of experiences he would have would be somewhat as follows.

During the night the passages would be charged with water-vapour to excess, and if the temperature was low the cell-walls lining the passages would probably be dripping wet, the quantities of water exuded depending on various circumstances, but being especially abundant on a cool night after a hot moist day. In the darkness, moreover, our hypothetical traveller in the maze of intercellular tunnels would find difficulties in breathing; for every cell would be pouring out small quantities of carbon-dioxide as the result of its own respiration of the oxygen of the air in the passages, and in certain states of the atmosphere we may picture the victim of the labyrinth having to keep near one of the stomata as his only chance of obtaining fresh air. At this orifice there would be draughts, moist air laden with carbon-dioxide passing outwards and drier fresh air pressing inward, the rate and quantity of flow depending on the differences of temperature, vapour-tension, &c., in- and out-side the leaf.

As the sun rose and illuminated the leaf, our traveller

would experience very distinct changes. A subdued greenish light would prevail in the intercellular passages, the sunlight passing through the green emerald-like chlorophyll-corpuscles having suffered absorption of most of the red and orange rays, though possibly other coloured lights might be present owing to reflections and refractions from the numerous surfaces.

At the same time the atmosphere of the passages would change considerably. The carbon-dioxide would fall to a minimum and the free oxygen would increase to a maximum, while the outrush of water-vapour at the widely gaping stomata would probably reach the dimensions of a perfect storm; but drier air would also pass in as fast as the pressure of the ocean of atmosphere outside could force it, though the rapidity of inflow would depend on a multitude of circumstances, one of the most important of which would be the rapidity with which the illuminated chlorophyll-corpuscles were decomposing the carbon-dioxide and setting free oxygen, and again differences of atmospheric pressure, saturation, temperature, &c., in- and out-side the leaf would come into play.

Of course it will be understood that these changes deal with such small masses that the phenomena are almost molecular; a point which must also be considered in relation to the size of the traveller.

In addition to the bombardments of the rushing molecules, our traveller in the passages would also probably perceive violent explosions in the cells as molecule after molecule of carbon-dioxide was torn asunder by the chlorophyll-machinery, and would feel or see the walls of the cells heaving in huge oscillations as the moving protoplasmic contents and cell-sap surged under the stress of the chemical forces at work, or of the physical displacements due to the rupture of the molecules and the

clashing together of atoms in course of reconstruction into new groupings. That his experiences would be varied, and periodically violent—on the scale presupposed—we may be sure, and although to our senses all these profound changes going on in the cells of a green leaf waving in the sunshine appear to be proceeding continuously and quietly, a little reflection must convince us that restfulness is the last attribute we can attach to machinery that is doing and undoing so much: setting free energy here and locking it up there, in forms that must mean powerful disturbances of the matter involved.

Let us now look somewhat more closely at the contents of the mesophyll-cells. These are principally the cell-protoplasm (*cytoplasm*) lining the interior of the cell-wall, and enclosing in its substance the chlorophyll-corpuscles, the nucleus and other bodies; and the cell-sap occupying the interior of the cell as a large vacuole, which the protoplasm envelopes and in which it is bathed.

All we need say here regarding the protoplasm is that it regulates the movements and constitution of all the other parts. It is in life continually undergoing changes, and the granules in its substance can be seen in movement: it is the living substance of the cell. All salts, organic materials, and so forth, however soluble in water, can only pass in and out of the cell through the protoplasm, and it is the protoplasm alone which regulates the supplies of watery solutions that can pass through the cell-membrane. This is easily seen on killing the protoplasm. Solutions held fast in the cell-sap so long as the protoplasm was alive—held so fast that the state of distension referred to as turgidity was possible—pass out at once as through a mere piece of muslin, when the restraining protoplasm is killed; and poisons, coloured solutions, or anything which can traverse the mere cell-

wall diffuse readily into the dead cell, whereas they would have been kept back by the living protoplasm.

The principal body in the cell for our purposes, however, is the chlorophyll-corpuscle. As the figure (Fig. 26) shows, numbers of dark rounded bodies, much smaller than the nucleus, are distributed evenly over the inner surface of the cell-wall. Each of these is a small mass of protoplasmic substance, somewhat like a minute sponge, impregnated with the green liquid known as chlorophyll, or leaf-green. Each of these chlorophyll-corpuscles is embedded in the living protoplasmic lining of the cell, and is therefore in direct contact neither with the cell-wall outside, nor with the cell-sap inside, and they present a peculiar green translucent appearance under the microscope almost comparable to emerald.

These chlorophyll-corpuscles, moreover, are not mere dead objects: they are capable of growth, division and movements, and we have every reason for regarding them as living bodies, though their life-activities are dependent on the life of the cell.

Experiments have shown that when the cells containing these green chlorophyll-corpuscles are properly supplied with water from the vessels of the venation, and with air containing carbon-dioxide from the intercellular spaces, and are at the same time exposed to fairly bright light such as that of a sunny day, certain minute colourless granules, shining in the green matrix like tiny pearls, make their appearance in the substance of the chlorophyll-corpuscles; and the application of suit[illegible] to these pearl-like bodies, as for ins[illegible] solution which turns them blue, proves that these colourless granules are grains of starch, a substance which contains carbon.

If, however, any of the conditions above mentioned are withheld—if, for instance, the light is too feeble or

too strong, or if no carbon-dioxide is allowed to reach the chlorophyll-corpuscle,—then these little starch-grains do not appear. And if the light, or the carbon-dioxide, or other necessary conditions are withheld too long, then the chlorophyll-corpuscles turn pale and die, and the cell containing them soon dies also. If the light is only withheld for a day or two, however, it is found that any starch already present slowly disappears; and we know that it is dissolved and turned into sugar and sugar-like bodies.

Now what is the meaning of all this? Put briefly, it means essentially that during the light of day, the carbon-dioxide which passes into the mesophyll-cells from the intercellular passages, is seized by the chlorophyll-corpuscles, and by means of the energy of the solar rays is broken up: its carbon is retained and made to unite with oxygen and hydrogen obtained from the water supplied by the vessels, and built up into the starch, sugars and such like carbonaceous substances referred to. It is from these carbonaceous bodies that the plant obtains its materials for forming new cellulose, oil, and other materials out of which new plant-substance is manufactured.

It would take up more space than I can afford here to explain what we know of the further details, but it is important to understand that during this process of *Photo-synthesis* of the carbonaceous food from carbon-dioxide and water, oxygen is set free and diffuses out into the intercellular spaces.

And now we see whence the efferent vessels of the venation get their supplies of sugars and such like carbonaceous bodies, and why our hypothetical traveller in the intercellular labyrinth would experience such great changes in the atmosphere of the tunnels according to the time of day or night.

In the daytime, especially if sunny, he would find the atmosphere rapidly getting drier and richer in oxygen, because the chlorophyll-corpuscles are consuming the carbon-dioxide and turning out free oxygen, while the water-vapour is rapidly evaporating into the drier air outside: during the darkness of night, he would find the atmosphere getting damper and damper, because evaporation is slower, while the cells are continually pumping more and more water from the afferent vessels, and the living cells are pouring out carbon-dioxide as the result of their respiration. For each living cell acts like an animal in so far that it consumes all the oxygen it can absorb from the air, and burns off some of the sugar-like carbonaceous bodies in its substance in order to employ the energy thus obtained for its life-purposes.

In reality this process of respiration goes on day and night, continuously, as long as the cell is alive; but in bright sunshine the breaking up of the carbon-dioxide (with evolution of oxygen) goes on so much more vigorously than the consumption of oxygen (with evolution of carbon-dioxide) that the latter process is more than compensated by the former, and our prisoner in the tunnel would find the atmosphere get richer and richer in oxygen as described.

CHAPTER X.

THE EPIDERMIS AND STOMATA.

Properties of the epidermis—Its protective functions—Stomata—Communication with the atmosphere and with the intercellular spaces—Numbers and distribution—Guard-cells—Development—Mechanism of opening and shutting—Sizes of stomata—Functions—Water-pores.

ALL that was stated in Volume I. pp. 81—91 concerning the epidermis as the bearer of hairs, prickles, wax and so forth, applies to the leaf as to the shoot, and we need only concern ourselves here with the epidermis as the regulating mechanism of the evaporation of the water-vapour which accumulates in the intercellular spaces.

We have already seen that the epidermis stretches as a continuous skin over the whole surface of the leaf. This skin consists of usually one layer of flattened or tabular cells, fitting closely and without intercellular spaces except at certain points to be referred to shortly; and two peculiarities are usually to be noted, especially in the epidermis of the upper surface of the leaf. One is that the epidermis-cells contain none of the green chlorophyll-corpuscles, so conspicuous in the mesophyll-cells beneath, though in other respects they resemble the latter in possessing the protoplasm, cell-sap, nucleus, &c., of a typical cell. The other peculiarity is that the outer walls of the epidermal

cells are thickened and hardened in a peculiar way so that they do not allow water to pass through in the easy manner in which it diffuses through the walls of the mesophyll-cells. The epidermis is, in effect, a more or less water-tight skin, and we can easily understand its function if we reflect how quickly the thin-walled and pervious mesophyll-cells would dry up in the sunshine if not protected by this covering. Indeed we can prove this by stripping the epidermis from a piece of leaf; or by removing a water-plant, the leaves of which have a very permeable epidermis, from its natural environment and noticing how quickly the leaf shrivels.

But although it is characteristic of the epidermis to have no ordinary intercellular spaces, it is equally characteristic of aerial organs that the continuity of their epidermis is interrupted at numerous definite points by definite apertures, like minute slits or mouths—and therefore termed *Stomata*—through which communication between the outer air and the intercellular spaces is assured. Each of these apertures is a slit-like opening between a pair of the epidermal cells, usually of special shape, and so far separated from each other by the development of an intercellular space between them, that a free passage is established between the external atmosphere and the intercellular spaces in the sub-epidermal tissues.

These openings are the *stomata*, and the paired cells which surround a stoma are termed *guard-cells*, for they are in most cases capable of so governing the aperture as to widen or narrow it, or even close it altogether, according to circumstances.

Stomata are found in the epidermis of all ordinary aerial organs, especially leaves, but they are usually (not always) absent from the epidermis of submerged aquatic plants, of most dry fruits and seeds, of subterranean leaves

and stems, and from the covering of the roots. They occur in very variable numbers on different plants, and on different organs of the same plant: they are usually most abundant on the true foliage-leaves, less so on the sepals and axial organs, but are commonly found in some degree on all the floral parts, and even on the integuments of the ovule.

The presence of stomata, and their communication with the intercellular spaces of the plant, can be easily demonstrated by the following simple experiment. A leaf of *Ranunculus Ficaria*, or of an Onion, &c., is fixed into a glass tube by means of gelatine poured around the petiole or other part in the tube. On immersing the lamina in water it is easy to force air-bubbles through the stomata by blowing, or to inject the intercellular spaces by sucking.

The positions and the numbers of stomata per square mm. of leaf-surface vary with the species of plant. Generally speaking they are most numerous on the under surface of ordinary thin foliage-leaves, and fewest on the thick leaves of succulent plants: facts in accordance with the transpiration and other requirements of such plants. Similar correlations between function and position are found in the restriction of the stomata to the upper surface of floating leaves (*Potamogeton natans*, *Hydrocharis*, Water Lilies, &c.); whereas they are usually confined to the lower surface in ordinary aerial leaves whose blades are horizontal, or at least are far more numerous there—e.g. Hornbeam, Birch, Pear, &c.—and especially in leathery polished leaves—e.g. Holly—they are confined to the lower surface: again in upright leaves (*Irideæ*, *Amaryllideæ*) and phyllodes, and leaves which hang with their edges up and down (Australian *Mimoseæ*, &c.) they are usually equally abundant on both sides.

As regards numbers, while species of *Sempervivum*, *Sedum*, &c., may have as few as 10 to 20 per sq. mm., the Cabbage has on the same area 700 or more beneath and 400 or more above.

There are 600 per sq. mm. in the Olive, 400 in the Oak, and about 100 to 300 on most ordinary leaves. Weiss found in 147 species of land plants examined, less than 40 per sq. mm. in twelve species, 40—100 in forty-two species, 100—200 in thirty-eight, 200—300 in thirty-nine, 300—400 in twelve, 550 in one, and 600—700 in three. In most of our trees and shrubs, 40—300 per sq. mm. have been estimated.

Much variety occurs also in the mode of distribution of stomata on the surface of the leaf. In the typical cases they are equally distributed all over, except over the veins. But in Grasses, Pines, Firs, &c., they are in definite longitudinal rows, and these stomatal lines are very evident as silvery streaks; or they may be in isolated groups, each with numerous stomata (e.g. *Saxifraga sarmentosa*, *S. japonica*, &c.); or in pairs, fours or sixes grouped over a common respiratory cavity—that is to say, a large intercellular space in the mesophyll—e.g. many Begonias. In *Nerium oleander*, &c., groups of stomata are found lining the sides of a deep depression in the surface of the leaf, each depression being lined by numerous hairs; and in most cases where the edges of the leaves are rolled together, or where furrows and depressions occur, the stomata are found only in the hollows, and often protected by hairs. Even more curious arrangements occur, as in the small Orchid *Bolbophyllum*, where the stomata are confined to the interior of hollow tubers which bear the minute leaves. In these cases of depressed and protected stomata we have no doubt adaptations to prevent the blocking of the stomata by

rain- and dew-drops, &c., and the same is true of the rolled leaves of the Ericaceæ, e.g. Heaths, Ling, &c.

There seems to be no doubt that the number of stomata per sq. mm. varies according to circumstances. Leaves developed in full sun have more than those developed in shade. On shoot-axes the stomata may be isolated and far apart, though leaves of the same shoot may have large numbers per sq. mm.

A typical stoma, seen in plan from the outside, shows the two *guard-cells* looking like a pair of curved sausages joined at their ends, and concave towards the slit-shaped aperture between them. In vertical section across the middle of the long axis of the stoma, the guard-cells look like two boxes with thin lateral walls, and with a thickened roof and floor. The thin lateral walls bounding the aperture are usually bulging towards one another, and their mutual advance towards contact closes the aperture more and more, while their recession opens it. It commonly happens that a stiff rim or ridge of the thickened roof overhangs the bulging wall, and there is often a similar ridge from the floor below. A fine hair passed through the aperture would project freely into a large intercellular space or *sub-stomatal cavity*, which communicates with the labyrinths of intercellular spaces of the tissues beneath, and we have shown already (pp. 91—96) what kinds of experiences would be in store for a minute organism which entered one of these.

The development of a typical stoma occurs as follows. While the epidermis is still young, a small cell is cut off by a partition-wall from one of the epidermal cells, and vertical to the plane of the latter; either from its end as in the prismatic cells of many Monocotyledons, or out of a corner, as in the tabular cells of most Dicotyledons, or even right out of its area by a more or less oval ring-like

partition as in many Ferns. This cell becomes the initial cell of the stoma. In many cases other cells are also cut off around the mother cell and invest it as *subsidiary* cells (e.g. *Commelyna*, *Sedum*, *Pteris*, &c.).

The initial cell, which is richer in living contents than the others, then becomes more or less regularly oval, and a straight median partition-wall, also vertical to the plane of the epidermis, is formed along its longer axis. This wall then splits, by the dissolution of its middle lamella, the process commencing in the centre and advancing to either end, and the aperture thus formed is the pore of the stoma, bounded by the two guard-cells: it leads directly into the simultaneously formed intercellular space (sub-stomatal cavity) below, and thence to the rest of the intercellular spaces of the mesophyll.

As the pore forms, the chlorophyll-corpuscles of the guard-cells attain their mature size and green colour, and the outer cell-walls become thickened: the neighbouring cells rarely develope the green chlorophyll-corpuscles. The cuticle also developes, and extends over the lips of the pore. Usually the floor, as well as the roof of the guard-cells, is also thickened; while the walls next the aperture and those adjoining the subsidiary cells or other epidermal cells remain thin and extensible.

The guard-cells thus formed are as a rule not only smaller in area than the neighbouring cells, but they are far less deep from roof to floor: it commonly results that they are sunk beneath the general level of the epidermis, though in rarer cases they project beyond the upper margins of the neighbouring cells.

Since the latter are almost invariably thickened and provided with a firm cuticular layer at their roof, while their floors and lateral walls in contact with the guard-cells are thin and flexible, the guard-cells are suspended

in apposition on a sort of hinge to the rigid roofs of their neighbours; hence any movement of the lower and lateral thin floors of the neighbouring cells caused by their distension or collapse, must cause the guard-cells to approach or recede from one another, and so narrow or widen the slit-like pore. Similarly, any distension or collapse of the guard-cells themselves must tend to drive apart, or to approximate, their rigid floor and roof, and so straighten vertically or bulge forward to meet one another, the thin walls bounding the aperture. Yet, again, any distension of the curved sausage-shaped guard-cells, with their mutually affixed ends, must tend to make their concave lateral walls recede from or approach one another; and it is obvious that in the mobility due to the exercise of these complex movements we have efficient mechanisms for the opening and closing of the stomata, though it is extremely difficult to follow the movements step by step in any given case.

Let us suppose, for instance, that the two guard-cells of a typical stoma are in a state of equilibrium such that their thick and rigid floor and roof are approximated elastically, and their thin lateral walls are not distended: the thin walls bounding the pore are then bulging towards and meeting one another, while the walls contiguous with the neighbouring cells are nearly straight in the vertical plane. Now suppose an influx of water into the guard-cells to occur and to distend them. Neglecting any other possible factors, the effect of the distension will be to drive the rigid floor and roof of the guard-cells further apart, and tend to straighten vertically the thin bulging walls bounding the aperture, i.e. to open the stoma.

Researches have made it probable that the opening of stomata in bright sunlight is really due to the formation, in the chlorophyll-corpuscles of the guard-cells, of osmotic

substances (i.e. substances with a powerful attraction for water) such as carbo-hydrates, and that the tension thus set up brings this very mechanism into play.

On the other hand, regarding the guard-cells for a moment as rigid, an osmotic influx of water into the subsidiary cells would tend to close the stomata; and other complications exist according to the distribution of the osmotic substances in these and other cells.

Apparently no simple generalisation covers all the facts, but we may say that in ordinary cases the stomata tend to be closed at night and in damp weather, because the epidermis-cells are then turgid with water and so drive the guard-cells together: in bright sunlight, on the other hand, when transpiration is at its maximum, these cells are more flaccid and so draw the guard-cells apart, while the latter enhance this effect by their own osmotic activity.

There are many exceptions, however, to the rule that the stomata are open in bright light, and it is abundantly evident that internal as well as external stimuli may be concerned.

As regards the sizes of stomata they vary in different plants. The averages estimated vary from 0·0002 to 0·0008 of a sq. mm. in area; and from 0·02 to 0·08 mm. long and 0·01 to 0·08 mm. broad, while the area of the orifice has been put at 0·00047 to 0·000137 sq. mm. The aperture at its widest in the largest stomata is about $\frac{1}{30}$ mm., and in the smallest about $\frac{1}{180}$ mm., the slit being about six times as long as broad. The largest occur in Monocotyledons such as Orchids, Lilies, Grasses, &c., and in Conifers: the smallest in Water Lilies, Olives, Figs, *Amaranthus*, &c.

Owing to their extremely small size it is obvious that stomata may easily become blocked by dew- or rain-drops, and many of the peculiarities of the epidermis are adapted

to prevent this—among other factors the waxy bloom, cuticular papillæ and rodlets, hairs, &c., or the restriction of the stomata to depressed areas, grooves, &c., or on the lower surface of inrolled leaves protected by hairs, &c., all serve this end.

It is stated that considerable differences exist in the power of opening and closing their stomata in different trees. The Aspen, essentially a tree of moist situations, is, according to Stahl, able to live on dry soils because it can close its stomata so completely that its leaves adapt themselves to the altered conditions; whereas most Willows are unable to do this, and suffer accordingly if planted in dry situations, and similarly the Birch and Alder are deficient in this regulating action.

That the stomata exert a powerful influence on assimilation, according as they are wide open and promote transpiration and the free access of gases, seems clear from Stahl's experiments with Lime, Honeysuckle, Lilac, Elder, &c., where he found that with closed stomata and drooping leaves no more starch was formed in the light.

Evergreen leaves—e.g. Yew, Box, Ivy—close up their stomata in autumn and thus husband their water-supplies in winter.

The stomata and pores so far described are adapted especially for the passage of water-vapour, and gases in general, but many plants are known to possess much larger apertures, similarly developed and constructed but adapted especially for the passage of liquid water when such occurs in excess in the tissues beneath. These are the so-called water-stomata or *water-pores*.

They are by no means uncommon on the submerged parts of aquatic plants, where they evidently replace the true stomata which such organs lack; but their most interesting occurrence is at the margins, apices and tips

of the teeth in aerial leaves, where their function—the exfiltration of water under pressure—comes into play when circumstances are unfavourable to the action of the ordinary stomata, for instance, when the atmosphere is saturated. Examples occur in *Fuchsia globosa*, *Primula sinensis*, Elder, *Cyclamen*, Saxifrages, Ash, Elms, Willows, *Prunus Padus*, Plane, *Corylus*, &c. Water-pores occur in some cases as temporary structures on young leaves, and are functional before the true stomata are completed, but shrivel up later—e.g. *Tropæolum*, *Colocasia*, *Aconitum*, &c. In the Aspen they occur on the leaves of seedlings, suckers and stool-shoots, but are said to be absent from the more motile ordinary leaves.

In some cases the water-pores are in groups, and may be of two sizes, e.g. a larger pore surrounded by several smaller ones (e.g. *Tropæolum Lobbianum*).

While the essential structure of water-pores is like that of stomata, their larger size, more curved guard-cells which are also incapable of opening and closing, and their relations to the tissues beneath are important points of difference. They lie over the ends of vascular bundles, the latter being usually dilated into a group of thin-walled gland-like cells, through which the water is filtered and exudes as drops at the pores. It should be mentioned, however, that such bundle-ends can exfiltrate water without the coexistence of definite water-pores; and in Grasses, for instance, drops of water escape through mere fissures in the epidermis, while in other cases ordinary stomata are utilised when the pressure of water is great.

It has been stated that as many as eighty-five drops of water per minute may exude from the large water-pores at the tip of the leaf of *Colocasia*, and that more than 22 c.c. have been collected in a single night.

An essential difference between this liquid water

pressed through the pores, and the watery vapour escaping from ordinary stomata, is that the former carries dissolved salts and other substances with it. In many cases large quantities of lime are held dissolved in the carbonic acid with which such water abounds, and on the escape of the gas and the evaporation of some of the water, carbonate of lime in some quantity accumulates at the teeth and other points where the water-pores exist. Such accumulations of chalk are characteristic of many Saxifrages—e.g. *Saxifraga crustata*, *S. Aizoon*, &c.—and are to be seen on the teeth of old leaves of *Salix fragilis*, &c.

It is not improbable that the water-stomata in bud-scales also act as relief to pressure; while in young leaves breaking through the bud the marginal teeth may begin their action very early, e.g. species of *Prunus*, *Platanus*, &c.

CHAPTER XI.

PHYSIOLOGY OF THE LEAF—MOVEMENTS AND POSITIONS OF LEAVES.

Principal function of the leaf—Photo-synthesis—Position of leaf—Curvatures and movements of leaves—Geotropic, heliotropic and sleep-movements—Mechanism—Nutations and periodic movements—Irritability—Leaf-mosaic—Drip-tips.

WE may now consider the life-actions—i.e. the physiology—of the leaf as a whole.

As we have seen, the leaf is in its typical form an organ adapted by its position, extension, shape, structure and other peculiarities, for the suitable exposure of the cells containing chlorophyll-corpuscles to the access of water, containing traces of minerals, and of air, containing traces of carbon-dioxide, and also of the light from the sun which is essential for the purpose of enabling the machinery of the chlorophyll-corpuscles to do its work of carbon-assimilation—the photo-synthesis which results in the building up of the organic substance of the plant. All our interest is primarily centred around this principal function of the leaf; and although many other functions, subsidiary to this one, are performed by the leaf in order to enable it to attain the object for which it is specially adapted, these secondary or subordinate functions ought

to be viewed always in proper perspective with regard to the chief one—carbon-assimilation or photo-synthesis.

Nor is this generalisation affected by the facts that particular leaves may be modified to perform quite different duties from those touched upon—e.g. they may act as climbing organs, floats, insect-traps, &c.—and that organs other than leaves may be employed for carbon-assimilation, either in addition to or in place of the typical leaves.

Consequently we are here concerned with a complex piece of physiological machinery—i.e. with an organ—the normal working of which can only be understood by studying its normal structure and relations to the natural environment on the one hand, and its behaviour in experiments on the other.

When the young leaf begins to emerge from the bud, it expands rapidly and is at first concave on the side next the centre of the bud, with its petiole or midrib nearly erect. As extension of the lamina proceeds, the upper surface grows somewhat more quickly than the lower, and this process results in the gradual throwing downwards and outwards of the flat organ, until its plane is more or less horizontal, and extended in some direction nearly at right-angles to that of gravitation and to the incident rays of the sun, or at least in a plane which exposes the surface to the maximum incidence of the sunlight.

Since compound as well as simple leaves effect this extension of their surfaces in darkness, as well as in light, and since the same position is regained by torsions of the petioles, or petiolules, if the leaves are displaced, the directive stimuli are probably to be found both in the interior of the plant and in its environment.

Experiments show that some of these curvatures are in part geotropic—i.e. the directive stimulation has

reference to gravitation—and in part heliotropic—i.e. they move in response to the stimulus of light—and the leaves displaying their surfaces in planes more or less transverse to the direction of light, and of gravitation, are said to be dia-heliotropic and dia-geotropic. Mere inspection shows that the leaves of a pendent or displaced branch of *Rubus*, Beech, Elm, Lime, *Philadelphus*, &c., regain their normal positions by curvatures of the petioles or the bases of the laminæ; and more exact experimental observations suggest that these curvatures are due to the unilateral growth of restricted parts which have not yet ceased to grow in length. This is particularly well seen in leguminous plants such as *Phaseolus*, where the growing region is the large pulvinus; but it is also visible in other cases, e.g. the Silver Fir, *Taxus*, &c., where the pulvinus is less evident.

While, therefore, the primary extension of the lamina is due to differences in growth on different sides, these secondary resumptions of position are due to the local growth of certain parts of the leaf, correlated with the action of gravitation or of light on the organ.

That the position of the expanded leaf is also in part a phenomenon of heliotropism, due to the directive action of light, is very evident. In many cases, especially among Monocotyledons, the incident light, and particularly the more refrangible rays, obviously induces retardation of growth of the young leaf; whereas in many Dicotyledons (e.g. Tobacco) the direct contrary appears at first sight to be the case, judging from the small size of the etiolated leaves of plants which have been allowed to grow in the dark.

It has been shown, however, that the last result is illusory, and due to a pathological phenomenon; for if the leaves of such Dicotyledons are periodically illumin-

ated with light of too low an intensity to induce the perfection and activity of the chlorophyll, they grow much larger in the dark intervals, suggesting that the feeble light renders something available for growth which could not be utilised in prolonged darkness. The powerful influence of incident light in directing the position of leaves is well seen in window plants (*Pelargonium*, *Tropæolum*, &c.) and in wall-climbers (Ivy, Vine, *Ampelopsis*, &c.), where the surfaces of the leaves are extended at right-angles to the sun's rays.

As maturity is approached some leaves exhibit the continued action of growth on their upper surfaces, by becoming convex towards the light; and others show the effect by becoming as it were pressed on to the surface of the wall up which the plant is growing (e.g. *Bignonia*).

Obscure as these phenomena are in their causal relations, it is at least clear that differences in the intensity of growth on the two surfaces, and geotropism and heliotropism, do much to determine the position of the expanded leaf; and that local variations in the rate of growth, stimulated by external agents, are the proximal causes of the normal position, which may be regarded as one of equilibrium decided with reference to the resultant of all the forces acting on the plastic organ. Moreover, this position of expansion of the maximum surface to the largest incidence of the solar rays is the most advantageous one for the organ.

So far, however, the assumption and resumption of position have been brought about by growth; but a time comes when the leaf is fully developed, and, so far as can be perceived, grows no longer, and nevertheless it exhibits movements—so-called spontaneous movements—which must, at least for the present, be distinguished from those brought about by visible growth. These movements are

due principally to internal causes, though they may be modified and directed by the directive action of gravitation and light as long as growth is still going on. The principal feature for us to notice here is that all these movements are adapted to bring the leaf into the best position for illumination by the sun's rays.

When the growth of the leaf is completed, it is nevertheless noticed that the position of the lamina is not absolutely fixed, but that it describes periodic alterations of position about a mean. Some of the most important of these variations are again traced to the action of light varying in intensity from hour to hour, and since the nocturnal variations are most pronounced, these sleep-movements are often called *nyctitropic*.

As the intensity of the light increases, the leaf raises or lowers the inclination of the plane of its lamina, and performs the reverse movement as the intensity of the light diminishes. Leaves have therefore a diurnal and a nocturnal position, and it is found that the rays of light which induce the diurnal position are the more refrangible ones: in red light the lamina assumes the sleeping position.

These nyctitropic movements of fully-developed leaves, induced by variations in the intensity of the light, are again, at least for the present, distinguished from the spontaneous periodic movements occurring in many leaves: the last remark is the more necessary, because the two classes of movements often conflict, rendering it difficult to trace them to their proximal causes.

It is owing to the nyctitropic movements of the leaves, and the different nocturnal positions of the more erect or more pendent laminæ, that plants like Clover, *Robinia* and other Leguminosæ, *Oxalis*, *Marsilia*, *Stellaria*, *Malva*, *Impatiens*, and even some Monocotyledons (*Maranta*, *Colo-*

casia, &c.) and Gymnosperms (*Abies*) present such a curious appearance if one illuminates them suddenly at night, by the electric light for instance. In some cases the petioles are found to have become more erect, and the laminæ to have folded up one over the other—e.g. *Trifolium*, *Vicia*, *Strephium*, &c. In others—e.g. Lupin, *Robinia*, *Oxalis*, *Averrhoa*, &c.—the laminæ become pendent from the erect, or slightly depressed leaf-stalks. Others, again, undergo displacements which direct the plane of the lamina, whether of leaflet or leaf, with its lateral edges upwards and downwards—e.g. *Coronilla*, *Arachis*, &c.—and other positions occur.

There can be little doubt that Darwin's explanation of these nocturnal positions of leaves, brought about by sleep-movements (nyctitropism), is the right one: they are adaptations to reduce the danger of cooling by radiation to a minimum.

In all these cases the mechanism of the movements depends on changes of turgidity in the cells of the pulvinus found at the base of each petiole or petiolule; and exact measurements show that the gradual erection or depression of the leaf-stalk or lamina concerned, as it passes from the diurnal to the nocturnal position, or conversely, is effected in jerks, so that the observed inclination at any moment is a variable one oscillating above and below a mean. The differences in the turgidity of the cells which bring about these erections or depressions are due to complex changes, resulting in variations in the amounts of osmotic substances and water in the cells of the pulvinus. That these changes are frequently induced by variations in intensity of the light cannot be doubted. But whether the abstraction of water (resulting in the diurnal position) is merely correlated with the increased transpiration in daylight, and the increased turgescence of the pulvinus at

night with the accession to the cells of such osmotic substances as sugars, acids, &c., as the sun goes down, or whether the light acts more directly on the protoplasm controlling the cell-vacuoles, are points not yet definitely settled by experiment.

Even more obscure, though no less certainly existing, are other movements of leaves known as spontaneous, and which are also doubtless to be traced to changes in the turgescence of the cells of the pulvinus.

The one feature they have in common is that they are apparently due to internal causes and occur independently of variations in the physical environment, so far as can be discovered.

At present, then, and usefully for our purposes, we may divide these movements into two chief categories, inasmuch as some of them are brought about by differences in the rate of growth of two sides of the whole leaf, or of parts of it, and cease altogether when the leaf is fully developed and has ceased to grow; whereas the others—the true spontaneous movements—occur by periodic changes going on in the fully-grown leaf, and are traceable to transient changes in the turgidity of the cells of the pulvinus.

The first of these categories results in *nutations*, or nodding movements of the leaf, owing to waves of enhanced growth affecting successively different sides of the petiole, or of the lamina, or of both together. Since these local accessions of growth usually prevail alternately above and below more than at the opposite sides, the course described by the tip of the whole leaf is usually a very narrow ellipse, with the long axis vertical, and approaches closely to a mere up and down movement in the vertical plane, but in some cases—e.g. *Camellia*, *Eucalyptus*, and especially *Cissus*, &c.—the ellipses are much wider, and in the last case, as also in many other twining plants, approach the circular and spiral form.

Strictly speaking, these nutations belong to the same order of phenomena as the curvatures of the growing leaf in the bud, and as they emerge from the bud state, but they may be conveniently regarded here because they result in definite up and down (and even side to side) movements of leaves which are already nearly fully developed.

Some leaves, and especially those of certain *Leguminosæ, Oxalidæ, Marantaceæ, Marsiliæ,* &c., exhibit quite a different set of periodic movements, however, and it is to these alone that the term spontaneous can be applied with any approach to accuracy; though even here the term is only applicable as an expression of our ignorance of the internal causes which induce the movements.

In the cases referred to, the leaves, or leaflets, describe jerking nutating movements, at intervals of a few minutes, day and night, provided the temperature and other conditions of the environment are not unfavourable to the general welfare of the plant.

In *Desmodium gyrans*, the Telegraph Plant, one of the best examples, the two small lateral leaflets oscillate in such a way that their midribs describe an inverted conical surface in from two to five minutes at intervals. The movement is jerky, and often very irregular in character, even in darkness or in a light of constant intensity, and is due to periodic differences of turgescence of the upper, lower, and lateral cells of the pulvinus, possibly induced by periodic alterations in the character of their osmotic contents. In most of the other plants referred to, the leaves simply move up and down.

It is clear that we do right in classifying this set of periodic spontaneous movements apart, for the time being; but it is also very probable that the only essential difference between them and the movements brought about by

differences in the rate of local growth, and movements of nutation generally, is that in these spontaneous movements the turgescence of the local sets of cells does not result in that fixation and consequent changes which we term growth. We might perhaps say that the cells begin to grow, but relax before the act of growth is consummated.

It is, however, scarcely worth while to enter further into the discussion of this complex matter of spontaneous periodic movements, because we are entirely ignorant as to how much or how little they can have to do with the physiology proper of the leaf. They must be looked upon as curious phenomena, more or less exuberant in nature, the further study of which is interesting because it may throw unexpected light on the nature of cell-life in general.

The last remark may also be applied to another set of curious movements of certain leaves, which are usually termed *irritable* movements—though no doubt all movements are really irritable—because they are usually only induced by mechanical contacts or shakings, which act as stimuli on the turgid cells of the fully-developed leaves when in a suitably irritable, or sensitive condition.

In certain species of *Oxalis, Robinia, Mimosa* and other Leguminosæ, the fully-extended leaves rapidly pass into a position more or less similar to the nocturnal one if violently shaken, or, in the case of some of the more irritable species—e.g. the Sensitive Plant (*Mimosa pudica*), *Oxalis sensitiva*—if a leaflet or pulvinus is merely touched with the point of a needle, or lightly squeezed between the fingers, &c. In *Dionæa* it suffices to touch a hair.

Perhaps the most startling feature in these cases of sensitive plants, is not so much that the contact or shaking suddenly induces the local change of turgidity of the cells of the pulvinus which causes the curvature of the leaf-stalk or lamina, as that this change is propagated from

one pulvinus to another in regular order. The phenomenon *is an irritable one, and we must suppose that the* determining *cause lies in the irritability* to contact or *shock of the living protoplasm of the cells touched* : the excited protoplasm then expels water from the cells, on the one hand, and transmits the stimulus, on the other, but we are as yet totally ignorant of the details of the mechanism by which either of the consequent phenomena is brought about.

The same is true of the sensitive movements, similar in principle but differing in detail, which result when the filaments on the leaves of *Dionæa* or *Drosera* are touched: the effect of the contact is seen in the rapid snapping together of the two halves of the lamina (*Dionæa*) or the slower incurving of the capitate filaments (*Drosera*). These latter examples, however, are evidently connected with the special functions, as insect-traps, of the leaves of these insectivorous plants; whereas we do not know what advantages are secured to the leaves of the Sensitive Plant, &c., by the irritable leaf-movements.

So far we have sketched the principal movements of leaves, some of which result in placing the lamina in such a position that its surface is fully exposed to the light and air surrounding it. We have now to trace the chief events which follow as it performs its principal function.

In the first place it must be understood that the living leaf, thus exposed to the environment, affects exchanges with the latter; and since its fluids are continuous with the fluids in the rest of the plant, there exist at least the conditions for exchanges with these also. As matter of experiment, we know that both events are accomplished, and it remains to show how this takes place in view of the organisation of the leaf, and its adaptations to this end.

For our purposes it must suffice to have established the fact that leaves move, and that most of their movements are connected with their continual striving—to use a word which, strictly speaking, conveys an erroneous meaning, since we are dealing with unconscious life—to secure the best attainable position for exposure to light and air.

Some curious phenomena are intelligible when this necessity for attaining the light-position is understood.

It is a noticeable fact that the small leaves of our ordinary trees, such as Beech, Hornbeam, Alder, Lime, Poplars and Willows, and shrubs such as Dogwood, Spindle Tree, Privet, *Hippophaë*, &c., are not usually segmented; and that segmentation is practically confined to large leaves such as Horse-chestnut, Ash, Walnut, Robinia, Maples, &c. It would appear as if some relation between the shading effect of leaf on leaf, and the size of the lamina, may be traced here, though perhaps it is unwise to generalise too far in this connection; for there may also be advantages secured in both by the display of many small leaves on a shoot, and by the cutting up of the fewer large ones into lobes or leaflets in connection with the exposure of the surfaces to violent winds.

Nevertheless it does appear significant that by having numerous crowded narrow leaves with short internodes in the spray—e.g. Pines, Firs, Yew, Larch, Tamarisk, &c.—or fewer and larger, but still relatively many and small simple leaves with somewhat longer internodes—e.g. Apple, Pear, Plum, Willows, &c.—the same effects as regards exposure to light and air are obtained as where still fewer and larger compound leaves cut up into numerous leaflets—e.g. Robinia, Horse-chestnut, &c. That is to say in all these cases we find the leaves or leaflets, however arranged, are so displayed as to shade each other as little as possible: the distances apart and

the position of the leaves and leaflets on their stalks are such as to ensure a maximum of lighting and aëration for each, and many of the peculiarities of petioles seem to be intelligible on the assumption that swinging movements from side to side—e.g. the pendulum movements of Birch leaves, and the lateral tremblings of Poplars—enable the otherwise partially shaded leaves to swing often into the light, and to catch the breezes.

But in many cases the shape of the lamina seems to be fitted for similar advantages. For instance in the Ivy (Fig. 27), Elm (Fig. 28), Lime, Hazel, &c., the base of

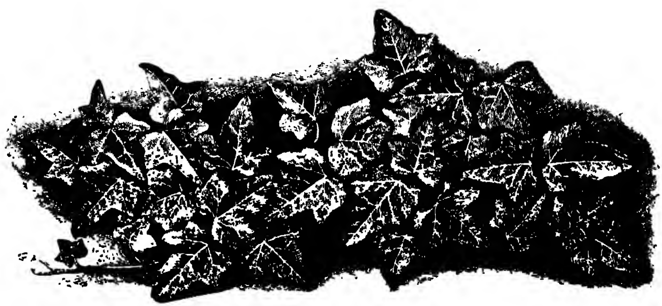

Fig. 27. Prostrate shoots of *Hedera Helix*, Ivy, showing leaf-mosaic (K).

the leaf is asymmetrical: whether the larger lobe in these cases is a shelter for the young bud, or an adaptation to fit the leaf-surface into the largest illuminated area is not clear. It is conceivable that both events occur.

Over-shaded leaves are often larger, and their palisade layers are of less vertical depth, than normally illuminated leaves: it may be that they thus obtain some compensation for the feebler light they receive, by exposing a larger surface to catch it, and a larger relative volume of spongy mesophyll to make the most of the depressed assimilatory activity.

But it must not be forgotten that the leaves of suckers and gourmandisers are also usually larger, even in full light; this seems referable rather to the large stores of reserve materials they have to draw upon.

In spite of these, and many other difficulties which at present obscure this subject, however, the fact remains

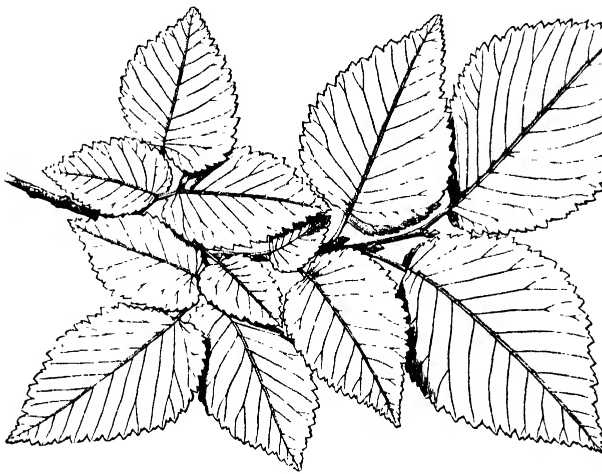

Fig. 28. Lateral shoot of *Ulmus*, Elm, showing leaf-mosaic (K).

that the length of internodes, sizes and shapes of laminæ, relative elongation of petioles, and the various movements of leaves, do generally fall in with the achievement of such disposition of the leaves on the spray at the outside of the crown of foliage, that the laminæ are exposed as fully as possible to the incident light and surrounding air.

We have only to look at the undisturbed spray of an Elm (Fig. 28), an Ivy on the ground (Fig. 27), or of a Maple, a terraced Cedar or Silver Fir and so on to gather the impression that such is the case, and the

accurate fitting in of leaf by leaf or lobe by lobe, like the pieces of a mosaic, has suggested the name of Leaf-mosaic for this phenomenon.

The manifold shapes and peculiarities of form and surface of leaves are at present inexplicable in detail, though we may suspect that the long pointed apices (drip-tips) of Ash, Norway Maple, *Viburnum Opulus*, &c., help them to run off superfluous water, which might clog the transpiratory activity if left hanging; appressed hairs and waxy coverings, glossy surfaces, &c., fulfil similar functions in other plants. It has been suggested that the trembling of Aspen and other leaves leads to the same end by shaking off the drops.

The resinous or gummy and slimy secretions on young leaves bursting from the bud may be rather anti-friction adaptations—e.g. *Prunus*, Alder, Hornbeam, Maples, Ash, Elm, *Viburnum*, and some Willows, &c.

CHAPTER XII.

PHYSIOLOGY OF THE LEAF (*continued*)—TRANSPIRATION AND RESPIRATION.

Transpiration — Experimental proof — Conditions affecting transpiration — Not mere evaporation — Regulation by stomata — Chloro-vaporisation — Significance of transpiration — Oxygen respiration—Experiments.

PERHAPS the most obvious function of the leaf is its *transpiration*—i.e. the giving off of water-vapour into the surrounding atmosphere—a process for which it is evidently adapted by its thinness, expansion, the numerous stomata, and the copious ramification of the vascular bundles (venation) and intercellular spaces.

It is easy to demonstrate the fact of transpiration by observing the loss of weight undergone by a leaf placed in a balance, or the bedewing of a cold bell-jar held over a living leaf; or, more exactly, by carefully fitting a leaf so that its petiole passes through a cork into one end of a U-tube filled with water, and noting the movements of the water in the distal leg of the tube, and the decrease in weight of the whole apparatus suspended on the balance, as water evaporates from the lamina. Similar experiments with whole plants prove the same.

That variations of temperature and moisture in the atmosphere affect the rapidity of this transpiration is also

readily proved by the foregoing experiments: the leaves transpire more water per hour in a dry than in a moist atmosphere, other conditions being equal, and more at higher than at lower temperatures. Under ordinary circumstances, however, one of the most potent factors in promoting transpiration is light: the leaves may transpire more than twice as much water per unit of time in full daylight as in darkness, and this phenomenon is of immense importance to the living plant. Naturally the leaves lose more water in a dry wind than in still air, other conditions being equal, but experiments also show that this is not as simple as it appears at first sight: the mechanical shaking of the leaves, by wind or otherwise, accelerates the transpiration owing to some action other than the merely more rapid removal of the moisture.

Transpiration, moreover, must not be regarded as the mere evaporation of water from the surface of the lamina: experiments show that, on the one hand, a dead leaf loses water more rapidly than a living one of the same size and kind, and that, on the other, the transpiration varies with the age of the leaf. As a rule the transpiration is most active in young leaves which have just finished their principal growth: leaves which are still growing in surface and thickness transpire less, and so do older leaves in which the cell-walls are becoming thicker and more indurated, and no doubt Höhnel is right in regarding the period of maximum transpiration as correlated with the perfection of the stomata, before the cuticle and cell-walls have become less permeable.

The intensity of transpiration, under like conditions, varies also in different plants. The rule is that herbaceous plants, and especially grasses, transpire more actively than trees and woody plants generally, while the process is reduced to a minimum in evergreens with thick coriaceous

leaves, and in succulent plants with pronounced cuticles. Some of these specific differences are correlated with such peculiarities of structure as the extent of the leaf-surface, the presence of wax and cuticular layers, and especially the number of stomata per unit of area, and other structural features; but there can be little doubt that more profound adaptations of the species to its natural environment also complicate the matter.

In the case of completely submerged leaves, transpiration, in the ordinary sense of the word, is of course out of the question, and it is but small in leaves which float on the surface of water. But marsh plants with their leaves in the air, even though moist, transpire large quantities of water in bright sunshine.

Enough has been said to show that transpiration is not a mere evaporation of water from the surface of a leaf; and it remains to point out that, in the typical leaf, the greater part of the aqueous vapour escapes through the stomata on the lower surface of the lamina, passing out of the intercellular spaces into which it had escaped through the thin cell-walls of the mesophyll. This being the case, the enhanced transpiration in brilliant sunlight has been attributed to the widening of the apertures of the stomata under the influence of light, and the consequent easing of the passage of the aqueous vapour to the exterior. It is true the stomata of many plants experimented upon do open wider as the light increases in intensity, and more vapour escapes from the stomatal area than from the upper surface of the leaf; but it is also to be noted that, according to Wiesner and Van Tieghem, the chlorophyll-corpuscles actually exude more water when active in the sunlight, and that most of the increased production of aqueous vapour in the intercellular passages is to be put down to this process, which the latter author terms

chloro-vaporisation. That it is really the light rays, and not merely the increased temperature, which thus promotes the escape of aqueous vapour from the cells containing chlorophyll, is shown by the experiments of the observers referred to, who have demonstrated that the maximum effect is in the blue and in the red-orange rays of the solar spectrum—i.e. the rays most actively absorbed by the chlorophyll, and that the process rises and falls with the process of assimilation.

In any case it is clear that the function of transpiration is admirably adapted for bringing water to the mesophyll-cells, especially at times when the leaves are receiving most light, and experiments show that this water comes through the vascular bundles of the venation, petiole, and wood-system of the stem and root, and therefore laden with soluble mineral salts derived from the soil. Since there is no question of any volatilisation of these mineral substances, it is obvious that they remain behind in the cells of the leaf, and it is of the utmost importance to understand that the whole meaning of transpiration is that it is a provision for bringing these necessary mineral ingredients from the soil to the living cells of the plant. The land plant has to transpire much water in order to obtain even a small supply of mineral salts, and thus, important as the function of transpiration is, it is nevertheless subsidiary to the principal function (photosynthesis) of the organ.

A second function performed by the living leaf is that of oxygen-respiration, common to all organs composed, as it is, of living cells. Much confusion has been caused in the past, partly by bad terminology and partly by misconceptions as to the real meaning of the process itself, and the student should clearly apprehend the significance of the following experiments.

When living green leaves are placed in the dark, they absorb oxygen from the air and give out an equal volume of carbon-dioxide, provided the temperature and other conditions of life are not interfered with; and the amounts of oxygen consumed and of carbon-dioxide evolved per hour can be readily estimated by any of the ordinary methods of gas-analysis. If normal green leaves are exposed in a closed atmosphere to a sufficiently bright light, however, the proof of their respiration is less easy, and depends on a thorough understanding of the process of assimilation; because the carbon-dioxide set free is at once reabsorbed by the chlorophyll-corpuscles and again decomposed into carbon and oxygen, and consequently the gaseous composition of the atmosphere does not alter essentially, a fact already known to De Saussure at the beginning of the last century.

If the last experiment is conducted under such conditions, however, that the light is too feeble to produce carbon-assimilation, the accumulation of carbon-dioxide in the closed atmosphere indicates that oxygen is being respired; and a similar result follows if etiolated leaves are allowed to remain in such an atmosphere, even in the light.

The fact is more directly established, however, by employing a closed atmosphere and shallow vessels filled with potassium-hydrate or some other body which absorbs and retains the carbon-dioxide as fast as it is formed: in such a system even green leaves in sunlight can be shown to enrich the environment with carbon-dioxide, because the potassium-hydrate absorbs this gas with such energy that it does not reach the chlorophyll, and is therefore not again decomposed. This experiment yields, in equal times, better results in diffuse light, and still better in darkness, because, as we shall see, the avidity with which

the properly illuminated chlorophyll-corpuscles seize and decompose carbon-dioxide is very great, and so some is sure to escape the potassium-hydrate for a time.

The best direct proof of the respiration of leaves in daylight, however, is that furnished by experiments which show that in an ordinary atmosphere, to which a little of the vapours of ether and chloroform are added, respiration proceeds normally, whereas the anæsthetics mentioned inhibit the chlorophyll-function.

The volume of oxygen consumed by green leaves is never less than that of the carbon-dioxide evolved, though it is very often found to be a little more: in very many cases, nevertheless, the volumes of oxygen absorbed and of carbon-dioxide given off are equal, or so nearly so that the difference may be neglected.

But in one and the same plant, under like conditions of temperature, &c., the energy of respiration differs in leaves of different ages: in the wheat, for instance, the young leaves gave 0·6 vol. of carbon-dioxide for every volume of oxygen absorbed, whereas the adult leaves evolved an equal volume of carbon-dioxide for every volume of oxygen consumed. Moreover the ratios differ at different seasons of the year, being greater in the spring and early summer than towards the end of the year.

Following the general law of respiration, that of the leaf also increases in intensity—as measured by the quantities of oxygen consumed in equal times—as the temperature rises to 40° C., or thereabouts; and the total results vary also with the intensity and kind of light, as also with the nature of the plant itself.

CHAPTER XIII.

PHYSIOLOGY OF THE LEAF (*continued*)—CARBON ASSIMILATION, OR PHOTO-SYNTHESIS.

Grand function of the leaf—Fixation of carbon—Experimental proof—Contrast between assimilation and respiration—Water-cultures—Conditions of assimilation—Amounts of carbon-dioxide employed—Evolution of oxygen—Bubble counting—Rays of light concerned—Spectrum of chlorophyll—Starch—Quantities formed.

THE grand function of the typical leaf, to which all its other functions must be regarded as subsidiary or accessory, is that of carbon-assimilation—i.e. the fixation of the carbon of the carbon-dioxide gas always existing in small quantities in the air, which carbon is then worked up into the structure of the plant; and, as we have seen, the leaf is to be conceived of as a complex piece of physiological machinery for carrying out this function in the best manner.

The essentials of the process of carbon-assimilation are the fixation of carbon from the carbon-dioxide of the air, and its addition to and assimilation into the substance of the plant, thus increasing its dry weight. This can only take place in green organs, especially the leaves, containing chlorophyll, and only in them when they are exposed to light of sufficient intensity. Moreover, the actual place where the process occurs is in the little

chlorophyll-corpuscles in the cells of the leaf, as we have seen.

The principal features of the process may be easily demonstrated as follows. A number of Mustard seeds are divided into four equal packets. Three of these portions are sown in as many pots of fine soil, and the other portion is placed aside. When the seedlings appear above ground in the three pots, one of the latter is exposed to full daylight close to a window, one far back in the room in faint diffuse light, and the third in complete darkness.

In a few days the plants exposed to full light will be found to be growing vigorously, their leaves deep green in colour, and evidently developing into normal plants. Those in the faint light will be "drawn" and "sickly" (to use the gardener's phrases) and obviously less vigorous as regards thickness of stems, size and depth of colour of leaf. Those in the dark will be very pale and watery, and much drawn (*etiolated*), and are evidently very weak and will soon die.

If we compare the dry weight of each of the three sets of seedlings, with the dry weight of the fourth packet of seeds which had been kept back for the purpose, we shall find that while that of the plants in diffuse light is considerably greater than that of the plants in the dark, it is decidedly less than the dry weight of our control seeds; whereas the dry weight of the plants fully exposed to the light will be greater than that of the seeds themselves.

In other words, the plants fully exposed to light have decidedly gained in dry weight: those in darkness have lost substance: and those in the feeble light have just about maintained their weight. Now what does this mean?

Careful analyses of thousands of such cases prove that

it means that the seedlings in the dark have lost much of their carbon by respiration, while those in full light have gained so much carbon that it far more than covers what has been lost in respiration: those in diffuse light, on the other hand, while they have more carbon than the plants in darkness, have gained far less than those fully exposed to light. All three sets of plants have lost the same proportion of carbon by respiration—a process always going on—but the plants in the light have recovered much more than they have lost, by means of carbon-assimilation in their green leaves.

Gain in dry weight—i.e. increase of carbonaceous substance—is one of the essential features in this process, and it now remains to prove more exactly that this increase is really due to the activity of the leaves, and not to that of the roots.

It is well known that a seed may be germinated over water, instead of being plunged in wet soil, and that so long as the seedling is supplied with sufficient water, it will develope into a young plant with root, stem and leaves, at the expense of the reserve materials stored up in the endosperm or cotyledons as the case may be; but that when these reserves are exhausted the plantlet dies unless other supplies are given to it.

Suppose, now, we repeat the foregoing experiment with seedlings germinating with their roots in water to which traces of the essential mineral matters of the soil are added—e.g. calcium nitrate, potassium nitrate, magnesium sulphate, potassium phosphate, and a trace of chloride of iron. It will be found that the same results are obtained. The plants in full daylight increase in carbonaceous dry weight, those in the dark decrease and soon die, while those in diffuse light just manage to keep going, for a time at least.

Now since there is no carbon in the water, beyond traces of carbonic acid which result from the respiration of the immersed roots, it is obvious that the assimilation of the carbon is due to the activity of the green leaves in the light of sufficient intensity. It is possible to carry the proof even further. It will be noted that a trace of iron salt was added to the water: this is because experiments have shown that the green substance—chlorophyll—is apt to remain in abeyance unless a trace of iron is present. If we omit the iron, and so deprive the seedlings of their green chlorophyll, even those fully exposed to light fail to increase their dry weight: they cannot fix the carbon, and soon die, because the carbonic acid at their roots is of no use to them.

It is clear then that the process of carbon-assimilation is dependent on the co-operation of sufficiently intense light, with the chlorophyll of the leaves, in air containing carbon-dioxide. Naturally, the astounding statement that green leaves waving in the air can snatch from the latter the minute quantities of carbon-dioxide it contains—about ·03—·04 per cent.—with sufficient avidity and rapidity to accumulate the large amounts of carbon-material in the plant, awakened vigorous scepticism when first promulgated. On reflecting that 10 cubic metres—i.e. 10,000 litres—of ordinary air contain only three or four litres of carbon-dioxide, only $\frac{3}{11}$ths of which are carbon and weigh less than 2 grams, while a fully grown Sunflower may contain 1000 grams of carbon fixed during its one summer's development, and an Oak tree many thousand times as much in proportion, the matter is certainly sufficiently marvellous.

The facts are, however, completely established by experimental evidence; and we have simply to correlate the enormous area of thin leaves, exposed to bright sunshine,

with the practically unlimited supplies of carbon-dioxide available in the atmospheric ocean passing over and in contact with them, and with the experimental proof that no other source of carbon is open to the green plant, to prove that the latter nevertheless *does* accumulate carbon to the extent stated.

Long before this was known, however, observations had established that green leaves in sunlight evolve pure oxygen gas. The fundamental experiment is easily repeated. A green water-weed, e.g. *Elodea*, is placed in water in a thin glass beaker, and a funnel placed mouth downwards covers the plant. Over the leg of the funnel an inverted test-tube full of water is placed, and the whole exposed to bright sunshine. In a few minutes bubbles of gas ascend the funnel and pass into the tube, displacing water, and accumulate in the closed upper end of the test-tube. In a few hours the tube may be filled with the gas, and the ordinary tests—ignition of a glowing match, absorption by pyrogallic acid—prove it to be oxygen.

The decomposition of carbon-dioxide in the chlorophyll-apparatus by the agency of sunlight is, then, as might be inferred, attended by the liberation of free oxygen; and as it can be shown that, in the normal process, the volume of oxygen liberated is equal to that of carbon-dioxide decomposed, it is possible to utilise the foregoing experiment for estimating the rate of the process, as follows.

If the stalk of an *Elodea* plant, well provided with leaves, is cut clean across, the escaping oxygen bubbles ascend at regular intervals into the funnel, and can be counted—so many bubbles per minute. On shading the apparatus the number diminishes; on intensifying the illumination it increases, and so on, within the limits of temperature and other conditions. The method of "bubble-counting" can therefore be employed to ascertain

with approximate accuracy the energy of assimilation under various conditions, and has been much used to determine which rays of light are most effective in assimilation.

If the apparatus is covered with a red glass bell, which only allows those rays of the solar spectrum on the red side of the blue end of the green to pass—i.e. the less refrangible rays—the number of bubbles per minute is not much fewer than in ordinary daylight, care being taken to ensure that other conditions are equal. If, however, a blue bell-jar is used which cuts off all the foregoing rays, and only transmits the more refrangible blue and violet rays, the bubbles diminish and fall to a minimum.

By the use of more refined apparatus, and placing the *Elodea* successively in the red, orange, yellow, green, blue, indigo and violet rays of the solar spectrum, a curve of intensity of assimilatory activity has thus been obtained, and although more accurate methods show that the bubble-counting method is not sufficiently reliable to warrant our regarding this curve as perfect, we may nevertheless trust the results for general purposes. They show that not only are the most active rays those in the red half of the spectrum, but that it is especially the red-orange rays which are most effective.

It is beside my purpose here to discuss the details of differences found by using different methods and different plants, but the student may accept as generally true that the process of carbon-assimilation in green leaves is due especially to the action of the red-orange rays in decomposing the carbon-dioxide, in the chlorophyll-apparatus of the living cells of the leaf.

The foregoing facts help us to understand why gardeners must allow plenty of air to circulate through their

green-houses when assimilation is going on, and why it is important to employ glass of a certain degree of transparency to the red-orange rays; why plants which flourish in full sunshine become "drawn" and "sickly" in the shade, and how important a part plants play in preventing the undue accumulation of carbon-dioxide in the atmospheric ocean, and in counterbalancing the loss of oxygen always going on owing to the tendency of this active element to combine with other bodies in Nature.

The large surface of the leaf, increased still more by the enormous intercellular excavations, and the thin semi-transparent texture, enable the chlorophyll-cells to obtain access to light and air to a degree impossible with most other organs; and we have seen that the normal mean position of the leaf, attained owing to its reactions during and after growth, is that of best exposure to the sun's rays, while direct observations have shown that the light passes into and some rays even through the mesophyll. The absorption-spectrum of a thin leaf, in fact, which is not essentially different from that of suitable solutions of chlorophyll itself, shows that the light chiefly absorbed is the red-orange, between the lines *B* and *C*, and to a less extent the blue and violet from a region in the neighbourhood of the line *F* to the ultra-violet, while the yellow and green are transmitted.

That it is the red-orange rays which are essentially concerned in carbon-assimilation seems to result therefore not only from experiments in which the number of oxygen bubbles are counted, and especially from experiments under coloured shades, &c., but also from the fact that it is just these rays which are so powerfully held back in the chlorophyll of the leaf.

It has been found, for instance, that green plants rapidly died of inanition in light which had passed through

a solution of chlorophyll so thin that it only absorbed the red-orange rays between the lines *B* and *C*; whereas they flourished as well in the light transmitted by a solution of potassium bichromate—i.e. the red-orange in question—as in that transmitted by pure water.

Hence we must conclude that although some of the blue-violet rays are also absorbed, they are employed chiefly for other purposes than assimilation: it is worth noting, however, that the process of chloro-vaporisation is most energetic in blue light, though it also occurs in the red-orange. No doubt we may conclude that the decomposition of carbon-dioxide is not the only work done in the leaf by the energy absorbed as light.

As to the quantity of light thus absorbed, it has been shown that it is considerable, and it is probable that much more energy is retained by the leaves than is necessary for the actual assimilation of the carbon.

Nevertheless the principal function of the leaves is to extend the chlorophyll-layers in the light and air, as said; and the success with which they attain this object is measured in various ways.

As we have seen, the actively assimilating leaf evolves large quantities of oxygen gas, the volume emitted being equal to the volume of carbon-dioxide decomposed, and much in excess of the small quantities of oxygen consumed in respiration.

The measurement of this gas-interchange has long occupied the attention of physiologists, since its discovery by De Saussure and others early in the last century; and the constancy of volumes of the carbon-dioxide absorbed and decomposed, and of the oxygen evolved, supplies a powerful argument in favour of our present theory of amylogenesis.

The volume of carbon-dioxide absorbed (and of oxygen

evolved) in a given time is by no means always the same, even in leaves of the same plant, and it differs considerably in different plants.

Experiments have also shown that, under the same conditions otherwise, a given leaf decomposes different quantities of carbon-dioxide in a given time according to the temperature, the amount of carbon-dioxide in the atmosphere, and the intensity of the light.

Each plant has, in fact, an optimum temperature for assimilation, beyond or below which it decomposes less carbon-dioxide per unit of surface in the unit of time; and similarly with the intensity of light, and the quantity of carbon-dioxide in the air.

Under certain circumstances, it is possible to make a leaf decompose more carbon-dioxide by adding an excess of that gas to the atmosphere, especially if the intensity of the light is increased at the same time; but the carbon-dioxide must not exceed 8 to 10 per cent., or the process of assimilation ceases owing to the injurious reaction on all the life-processes, and even these quantities—which of course are relatively enormous, since the atmosphere only contains ·03 to ·04 per cent. as a rule—can only be endured for a short time and in a bright light.

The best proof of increase of weight by assimilation in the leaves, however, is the following, the principle of which was discovered by Sachs.

A stencil-plate, with a figure, letter, &c., cut out in it, is laid on the upper surface of a leaf of a Vine, Cabbage, or other ordinary plant early in the morning of a bright warm day, before sunrise, and the sun is allowed to shine directly on the surface thus treated for a few hours: then the leaf is cut off, and is at once plunged into boiling water for a few seconds, and decolorised in warm alcohol. When all the chlorophyll has been thus extracted, the white or

yellowish leaf is then placed in an alcoholic solution of iodine for a few minutes, and finally washed in distilled water. The result is shown by all those parts of the lamina which contain starch being coloured deep violet-blue, and, if the conditions of the experiment are properly observed, these parts will be those exposed to the light—e.g. the letter or figure cut in the stencil-plate. In the summer, with strong sunlight, it is even possible to obtain prints from coarse photographic negatives in this way.

A modification of this procedure has been employed by Sachs to determine the quantities of starch formed per hour per square metre of leaf-surface, and although these quantitative results can only be approximate the experiments are as instructive as they are ingenious.

CHAPTER XIV.

NON-TYPICAL LEAVES AND THEIR SUBSIDIARY FUNCTIONS.

The leaf the most plastic organ of the plant—Heterophylly—Conversion of leaves to bud-scales—Leaves of Conifers—Relative transpiratory activity of various trees—The Larch—Adaptation to environment—Floating and aquatic leaves—Rolled leaves—Leaves of arid situations—Adaptations to prolonged drought—"Switch plants"—Leaf-tendrils and leaf-spines—Phyllodes and Phylloclades.

THE student is now acquainted with the principal types of leaves and their chief functions. It remains to enquire more closely into cases where modifications or alterations of form and structure, and even of function, disguise the characters of the leaf; and we shall find that these have gone so far in some instances, that no one would suspect at first sight that the given organ is a leaf at all.

It will be remembered that we found plenty of examples in the leaves of the Leguminosæ of special adaptations to peculiar purposes. Who would suppose that the tendril of *Lathyrus Aphaca*, for instance, is a leaf, unless he had compared the transitional cases?

So numerous and important are the modifications in leaves, that it is hardly too much to say that the student who is well versed in them and their interpretation has

grasped the main features of the botany of the higher plants. For the leaf is the great plastic organ of the plant, and responds more readily than any other organ to the vicissitudes of the environment, the result being alterations in its size, texture, form and functions, so profound in many cases that its typical leaf-nature is completely obscured.

The fundamental principle to be grasped here is that in the adaptation of plants to their environment, advantages are often gained by one and the same organ undertaking several duties. We have already seen how foliage-leaves vary on the plant in cases of heterophylly (e.g. *Ranunculus aquatilis*); and the differences between the cotyledons and the leaves which follow (e.g. Hornbeam), and those between the lower leaves of a plant and the stem leaves higher up (e.g. *Brassica*) are all examples of the same category. So also are the following. In many cases the last leaves of the current year's twig of a tree become bud-scales (e.g. Horse-chestnut) and as such are reduced in size, altered in form and texture, and otherwise so changed from the type that everyone agrees to give them another name—bud-scales. The scales of winter-buds, however, are oftener stipules than leaves, though the difference does not much concern the principle. Bulb-scales, again, are merely altered leaves, and other examples can be given.

The student will find it useful to begin asking the meaning of these variations in the structures and functions of leaves, even at this stage, since no part of the plant —probably no organ in any organism—affords better material for facts whence deductions may be made in the discussion as to the origin of specific forms. Leaves vary both in direct response to external conditions—e.g. light, drought, temperature—and in response to internal stimuli

which we cannot directly refer to the action of the environment.

Those variations which, in a given situation and season, are dangerous to the life of the plant, may be exterminated by the rigour of the environment; whereas those variations which make for adapting the plant a little more to the conditions prevailing at the time, are apt to be preserved. A race of plants may thus be produced more adapted to the environment than ever before.

This is the gist of the argument for Natural Selection, and it certainly promises a better explanation of the following cases than any other hypothesis. Indeed the only alternative is to appeal to unsubstantiated hypotheses which not only offer no explanation of the phenomena at all, but which lead us into a nightmare of illusions quite outside the evidence of Natural Science.

That the narrow leathery leaves of Conifers, such as Pines, Firs, Cedars, &c., are adapted to the peculiar conditions of their natural habitats can hardly be doubted. Being evergreen, they are peculiarly exposed to two dangers in their Alpine homes: namely to being intensely heated and illuminated by the direct solar rays, in very clear weather and at periods when the roots are still in frozen soil and inactive, and, secondly, to the danger of accumulations of large and weighty coverings of snow during the winter. An adaptation which appears to meet the first danger seems to be their low transpiratory activity. They have a very thick protective cuticle and expose but small surfaces to the air; the stomata are few and sunk in grooves; and their vascular supply is minute. In accordance with this we find that they transpire far less water than do similar areas of the broad thin leaves of Dicotyledons, as shown by the following determinations made by

Von Höhnel, who estimated that the proportion of water transpired in equal times by the same dry weight of leaf substance was on the average as follows :—

Ash...	85,614
Birch	81,433
Beech	74,858
Hornbeam	72,973
Elm	66,170
Sycamore	58,595
Oak	54,572
Norway Maple ...	53,063
Spruce	13,501
Scots Pine	9,426
Silver Fir	7,178
Black Pine... ...	6,734.

Whence we see that the Pines, Spruce and Silver Fir transpire very much less water than any deciduous tree examined. As the result of prolonged investigations it was concluded that where the water-supply is sparse, the Conifers transpire about one-tenth as much as do the deciduous Dicotyledons, but where there is plenty of water the proportion may rise to one-sixth or one-seventh as much.

Now it is interesting to note that there is one Conifer, —viz. the Larch—also with narrow leaves, which for a time may transpire as vigorously as do the most active of the Dicotyledons referred to, e.g. the Ash (which, with the Birch, Lime, Alder and *Pyrus torminalis*, is one of the most powerfully transpiring trees in Europe), and at first sight it appears as if we had here a serious contradiction, for the Larch is an Alpine Conifer of the highest altitudes. Such is not the case, however. The Larch simply faces the conditions with a different equipment of adaptation : its narrow and delicate leaves *are deciduous*, and are

therefore not exposed to the dangers of the Alpine winter.

The danger of breakage of the ordinary Conifers by the accumulation of snow is also met by the ease with which the glossy narrow leaves shoot it off at steep angles when the weight becomes critical.

Moreover the narrow form has other advantages, e.g. against chilling by radiation, the shearing action of high winds, and so forth.

We have seen that the typical leaf is a thin and flat organ exquisitely adapted for the performance of certain primary functions—transpiration, assimilation and respiration—which depend on its exposure to light and air, and the accessibility of gases to its interior through the stomata and intercellular spaces.

Many plants, however, are in such a position that they must either modify the structure of their leaves in accordance with peculiarities of climate, soil, intensity of light, &c., or give up forming thin aerial leaves of the typical form altogether; and we may safely assume that only such plants as have varied in the necessary directions, and have been selected out to fit such conditions, have been able to persist in the positions referred to. Such plants are known as Xerophytes. In other words, plants innumerable during the ages gone by have in vain been carried by wind, water, or animal agencies into such situations as deserts, salt-plains, marshes, mountain tops, &c., because their leaves are too thin and delicate to withstand such exigencies as intense cooling by radiation, brilliant sunshine, flooding with water, persistent drought, &c.; and only such as varied in some direction which proved of advantage to meet the new conditions could survive and leave progeny more and more fitted to the altered environment.

We meet with indications of this everywhere, and in some of the situations referred to the modified leaf-structure is so remarkable that we must examine a few examples and compare them with the type.

We have already seen that floating leaves have their stomata above, and submerged ones have usually none at all; and that the venation of aquatic plants generally is inconspicuous, because there is no active ascent of water to meet the requirements of transpiration in dry air and which would demand a voluminous system of pipes (vessels); also that there is no need for strong supports (fibres, &c.) to carry the weight of the leaf and keep its lamina stretched in the air. Similarly the tissues of water-plants are thin and soft, and no thick cuticle or other protection against excessive evaporation is needed.

If we contrast the leaves of plants adapted to the other extreme of environment—i.e. situations liable to prolonged drought—it is suggestive how common are leaves closely rolled up and exposing little surface, or covered with dense blankets of hairs, wax, thickened cuticle or other protection against the access of solar rays; or such as have close-set thick-walled tissues and few stomata, or provided with stores of water held fast by special water-holding cell-contents; or leaves exhibiting simultaneously two or more of these and other peculiarities, which suggest adaptations against difficulties of obtaining or keeping their water-supplies in time of drought.

Many such plants—especially those inhabiting persistently arid regions such as true deserts—have given up forming leaves at all—e.g. many Cacti—but I am here concerned with plants which do form leaves, and such leaves, to be able to exist at all, must be adapted in some way for protection against excessive transpiration.

A word of warning is here necessary, however. It is

not established by scientific evidence with regard to any plant, that its leaves *must* be modified in any particular direction to meet such conditions as have been referred to; nor is it proved that any of the peculiarities of structure mentioned are adaptations solely against drought. For, with regard to the first point, we find leaves meeting the exigencies of a dry climate in very many different ways; and, with regard to the second, a structural peculiarity may serve one plant as a protection against drought, and another plant—in an apparently very different environment—may exhibit similar structural variations adapted to meet quite another chain of vicissitudes. All that can be said at present, while this subject is in its infancy, is that plants which flourish in excessively arid situations, invariably exhibit peculiarities which suggest adaptations to the peculiar circumstances. This matter is so important, and misapprehensions have given rise to such strange mis-statements, that I may illustrate it by a few further examples.

In a region where the spring is marked by two or three months of wet weather, while all the rest of the year is a season of drought, numerous plants with very different habits may exist. Some are short-lived annuals: their seeds germinate and the shoots bear typical flat thin leaves, the flowers appear early and the fruit and seed ripen rapidly, so that the whole life-cycle is completed by the time the dry season sets in. Others are bulbous, putting forth their thin leaves quickly in the spring, and maturing as before before the dry season sets in: the bulbs below ground being renewed before the leaves wither away, and remaining buried and dormant during the drought. In such cases the plants or their leaves may escape the necessity of special adaptations to avoid over-transpiration. Many trees and shrubs also

rapidly put forth thin leaves during the rainy period, and these fall by the time of drought. Other plants escape the dangers of drought by assuming the fleshy, cactoid habit and store water in their fleshy shoots, but form no leaves. It is, therefore, especially in the case of perennials which retain their leaves during the dry season, that the adaptations we are concerned with are found, and if we meet with a case where, in an arid climate, such leaves appear to be typically thin, flat, and with large surfaces, &c., the probability of further study of its habits revealing some special adaptation as yet undiscovered is shown by experience to be great.

Many leaves are rolled up, the edges being curved upwards in some, such as Fescue, *Stipa*, *Ammophila* and other grasses, downwards in others, such as *Empetrum*, Heaths, Ling, and other *Ericaceæ*, *Epacrideæ*, Rosemary, &c.; and it is suggestive that many of these plants are evergreen and live on moors, alps, sea-shores and such places where the air is often dry for long periods and where cold dry winds sweep their surfaces at intervals. It is further suggestive that such leaves are reduced in area by the rolling, have thick cuticles, and that their stomata are few and are situated on the concave surface. Some of these leaves are erect, e.g. the Grasses, others closely overlap, e.g. the Heaths, and most of them are covered with a waxy bloom on the exposed surfaces, e.g. *Ammophila*, or with a tomentum of hairs on the covered-in stomatal surface, e.g. Rosemary, &c.; all of which peculiarities appear to be adaptations to reduce the dangers of excessive transpiration. Indeed, this suggestion receives support from the observation that some of these leaves unroll themselves out flat in dull and moist weather—e.g. *Ammophila*—and close up again in drought.

As a further illustration of the difficulties of explaining the teleology of these adaptations it may be pointed out that rolled leaves are characteristic of many plants which, apart from periodical exposures for long periods to intense isolation and drought, are liable to be heavily wetted at intervals by mist, dew and mountain rains; and the suggestion has been thrown out that the stomata thus escape being blocked up by drops of water, owing to their position in the grooves, and to the presence of hairs, wax, &c., on the cuticle, so that the gas-interchanges are not interfered with, even though the leaves of these mountain and moor plants may be dripping with moisture in the early mornings of days which will be hot and dry later.

Yet another suggestion has been made regarding inrolled leaves, namely that the air imprisoned in the cavity by the inrolled margins acts as a protection against the excessive chilling to which these plants are exposed.

Another structural type of leaf, in part also characteristic of plants exposed to the conditions referred to above, is the cylindrical or terete leaf of Rushes, *Hakea*, Onion, *Isoetes*, *Subularia*, &c.; such are hardly distinguishable from the likewise cylindrical stems of similar and of many leafless plants—Switch plants—e.g. species of *Scirpus*, *Carex*, *Juncus*, *Equisetum*, *Spartium*, &c.

In the leaves referred to the structure is *radial*, the green tissues and the epidermis with its stomata being distributed radially around the centre, and presenting no upper and lower sides as in the typical *bi-facial* type of ordinary leaves.

It is not evident that adaptation to any one factor of the environment can be regarded as probable in these cases; because, although such characters as the erect position, depression of the few stomata in grooves, reduction of the transpiring surfaces by the assumption of

a cylindrical form, and protection by a thick cuticle, &c., are characteristic of some of them growing in dry climates or on exposed moors, hills, &c.—e.g. *Hakea*, Rushes—others, e.g. *Subularia, Isoetes*, grow more or less completely submerged in water, and some species of *Allium* are meadow plants. Whether these erect Juncoid leaves are of advantage in such exigencies as the drying up of the shallow water in which they grow may be a question: it appears probable that plants with their roots in cold wet soil—e.g. *Juncus, Scirpus, Carex, Equisetum*, &c.—may have considerable difficulty in absorbing water sufficiently fast to supply a copious transpiration-current to the leaves in the air above on a hot sunny day, and this state of affairs is common in the case of such plants.

The suggestion has also been made that the radial structure facilitates equal illumination on all sides in Polar regions, where many such plants are found.

Many plants are so modified that their leaf-nature is not obvious at all, as in the case of tendrils and leaf-spines; while in other cases we find flattened branches (*phylloclades* or *cladodes*) replacing leaves.

With regard to the latter, there is an adaptation met with in the leaves of many *Acacias* whereby the whole leaf is reduced to a flattened petiole which assumes some simple leaf-like form, but has its edges vertical. Such *phyllodes* can be recognised from their axillary buds, their venation, freedom from scale-leaves, and in many cases may be seen in all stages of transition to ordinary leaves on the young plants. Again they are bilateral in structure, not dorsi-ventral like ordinary leaves.

The fact that phyllodes occur in plants of brilliantly lighted regions, e.g. Australia, where the lamina of evergreen leaves of trees like *Eucalyptus* also tends to place itself edge-on to the incident light, has suggested that

they are specially adapted to avoid excessive illumination. Support for this explanation is found in the similar edge-on position of many ordinary leaves of alpine and prairie plants, &c., developed in intensely lighted regions: thus the leaves of species of *Silphium* (so-called "Compass plants"), *Lactuca*, &c., are twisted on the petiole and placed in the plane of the meridian, and the isobilateral, erect leaves of *Iris*, *Narthecium*, *Tofieldia*, *Phormium*, &c., also tend to put themselves edge-on to the light.

It should be noticed, however, that the assumption of the vertical position by ordinary leaves, cotyledons, &c., is often brought about temporarily by movements of the petiole and pulvinus, as already explained. Thus the cotyledons of many Crucifers, Leguminosæ, Compositæ, &c., are horizontal during the day and vertical at night. Obviously there is here no question of avoiding excessive illumination, and Darwin has shown that chilling by radiation is the danger escaped by this adaptation. Similarly in the case of leaves which either erect their lamina, e.g. species of *Coronilla*, *Mimosa*, *Acacia*, *Gleditschia*, *Nicotiana*, *Marsilea*, &c., or let it hang pendent during the night, e.g. Clover, *Lotus*, *Oxalis*, *Averrhoa*, *Lupinus*, *Melilotus*, *Desmodium*, the vertical position of the leaf-surface lessens the danger of chill.

Nevertheless these cases do not contradict those where the vertical position is assumed by leaves during the intense heat or glare of the tropical day, such as those referred to, and *Leucadendron*, *Melaleuca*, *Protea*, *Grevillea*, *Banksia*, &c.

PART II.

SPECIAL.

In order to facilitate the running down of species in the following classification, the signs in the accompanying list are used in sequence and indented as below:—

I
A
1
a
i
α
*
†
⊙
▱
§
#
÷
8
Δ
☄
☄☄
ΔΔ
8 8
÷ ÷
##
§§
▱▱
⊙⊙
††
**
β
ii
b
2
B
II

CLASSIFICATION OF TREES AND SHRUBS ACCORDING TO THE CHARACTERS OF THE LEAVES.

I. LEAVES COMPOUND: THE LEAF-SEGMENTS COMPLETELY ISOLATED, AND EACH JOINED TO THE COMMON RACHIS BY ITS OWN PETIOLULE, OR SEPARATELY INSERTED ON IT.

[For] p. 17

A. LEAVES OPPOSITE, AND, ON THE ERECT SHOOTS, USUALLY DECUSSATE.

[For] p. 15

(1) Leaves pinnate, all with a terminal leaflet—i.e. imparipinnate.

[For (see p.

(a) Leaflets few, about 5—7, and broad, more or less ovate, on long petiolules some of which twine as tendrils; venation reticulate, quite exstipulate; shoots slender.

[There are no British trees or shrubs with paripinnate leaves. Shoots with apparently distichous evergreen simple leaves may possibly suggest resemblances to the beginner—e.g. Yew, Silver Fir, &c.—but he will note buds in some of the leaf-axils.]

Clematis vitalba, L. Traveller's Joy, Old Man's Beard (Fig. 29). A climbing hedge-shrub, with long slender 6-angled shoots. Leaflets about 5—7 (3—9), on long petiolules, some of which coil as tendrils round other twigs and then persist for some years. Rachis up to 6—7 cm. long. Lamina thin, 4—10 cm. long and 2—5 broad, oval-acute to ovate-cordate, entire or with a few coarse teeth

or almost lobed. Exstipulate. Glabrous, or slightly pubescent beneath. The persistent old coiled leaf-stalks are very characteristic. Leaves out early and remaining

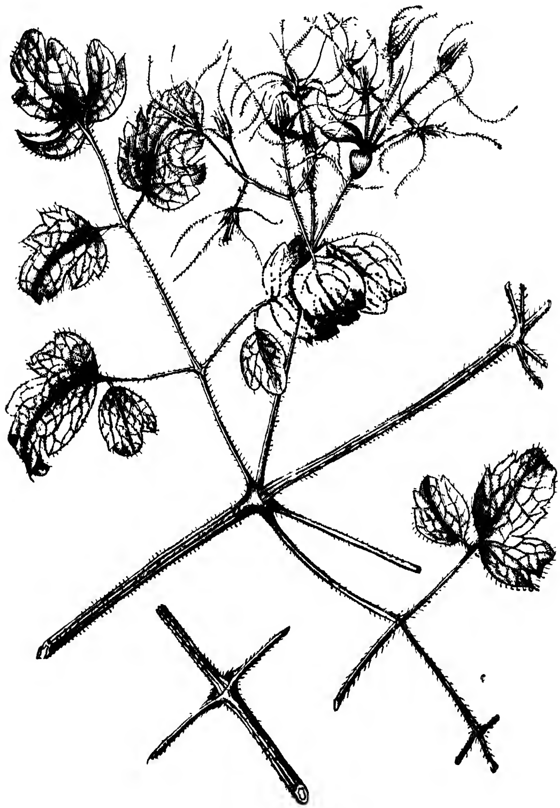

Fig. 29. Traveller's Joy, *Clematis vitalba*, p. 151 (Sch).

late: dark brown or nearly black on withering. The uppermost leaves may be merely pinnately lobed, or trifoliolate. Young shoots silky-pubescent. Venation

pinnate, pseudo-palmate at the base, looped and reticulate, with a tendency to form infra-marginal veins.

(b) Leaflets more or less lanceolate, on very short petiolules or sessile: never twining, shoots stout.

(i) Stipules represented by a thin interpetiolar ledge or line. Petiolules short. Venation reticulate, with large meshes.

Sambucus nigra, L. Elder (Fig. 30). Shrub or small tree: shoots with large white pith and prominent lenticels.

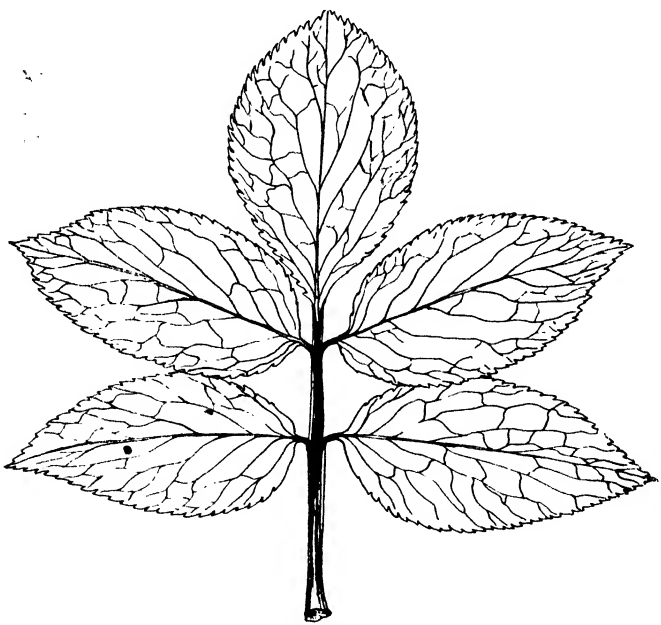

Fig. 30. Elder, *Sambucus nigra*, p. 153 (D).

Leaves 20—30 cm. in total length. Leaflets about 5—7, or even 9, on short petiolules. Lamina thin, not obviously

articulated, and often obliquely attenuated below; ovate-lanceolate or elliptic-lanceolate, acute or acuminate, coarsely and sharply or cuspidate-serrate, 3—9 cm. long (3—15 × 3—6 cm.); glabrous above, often with scattered hairs on the venation beneath. Petiolules and rachis grooved above: stipules obsolete, represented by an inter-petiolar ledge or line joining the leaf-insertions. The lower leaves occasionally trifoliolate. Leaves emerge very early and remain late, dying off yellowish green.

Venation of leaflet pinnate-reticulate, the secondaries irregularly sinuate, and rapidly breaking up with the tertiaries into large polygonal meshes, oblique to the long axis, and not traceable to the margins; or with a slight tendency to loop.

(ii) Leaf exstipulate. Leaflets sessile or sub-sessile: venation pinnate.

Fraxinus excelsior, L. Ash (Figs. 31, 32). A large tree, with stout woody shoots, often compressed, and leaves up to 30—40 cm. long. Leaflets about 9—13, or occasionally 15, sessile, articulated, ovate-lanceolate or lanceolate, acuminate, coarsely and unequally sharply serrate, attenuate and entire at the base; each 3—9 (3—15 × 2—3) cm. long, thin, glabrous, and green above, paler and with traces of pubescence near the margin or on the midrib below. Lower leaflets shorter than upper. Rachis stiff and tough, channelled above, with a prominent pulvinus and leaving a large scar. Exstipulate. Leaves emerge late, after the flowers, and turn brown and yellow in autumn, disarticulating as they fall.

Venation pinnate, the secondaries nearly straight from midrib to margin, slightly sinuate and curved upwards, and looping just beneath the margins, where, with the

tertiaries, they almost form an infra-marginal vein. Tertiaries reticulate into a fine meshwork.

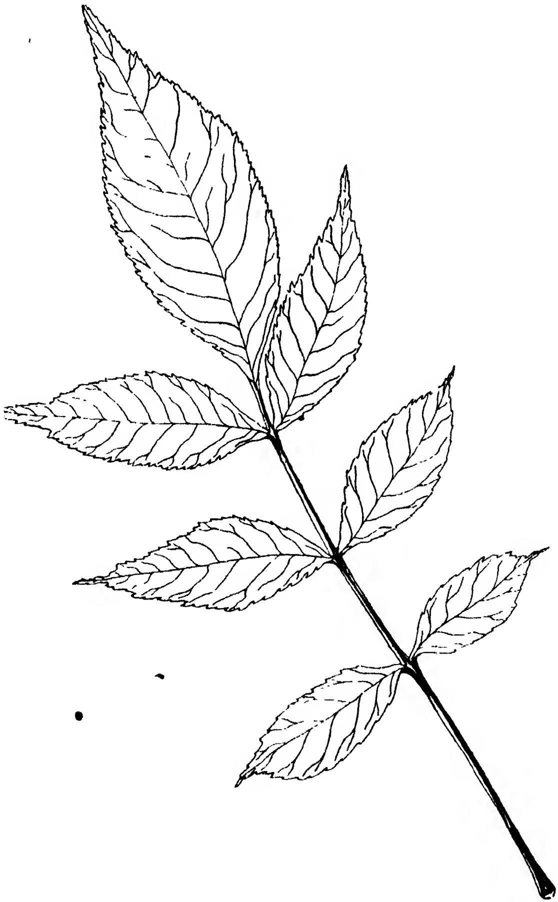

Fig. 31. Ash, *Fraxinus excelsior*, p. 154 (D).

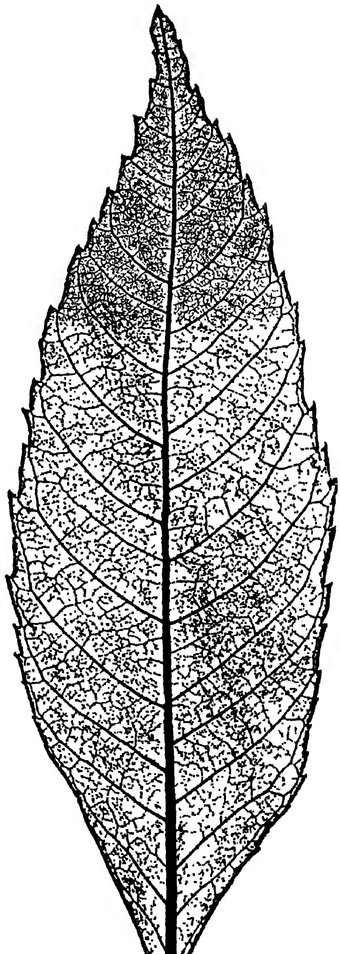

Fig. 32. Leaflet of Ash, *Fraxinus excelsior*, p. 154 (Ett).

(2) Leaves palmately compound, digitate, exstipulate.

Æsculus Hippocastanum, L. Horse-chestnut (**Fig. 33**). Large tree with stout shoots, and large digitate **leaves** on a long petiole with broad *insertions* and *prominent*

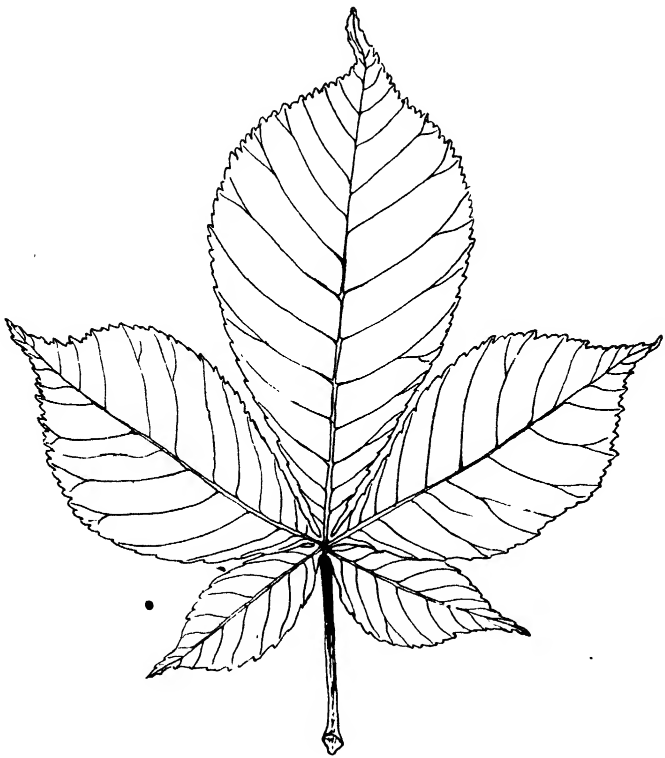

Fig. 33. Horse-chestnut, *Æsculus Hippocastanum*, p. 157 (D).

pulvinus; exstipulate. Leaflets 7 (or rarely 5), large, thin, 6—12 cm. or more long (8—20 × 4—10 cm.), obovate-

lanceolate, or cuneate-obovate, tapering below and suddenly acuminate at the apex, unequally serrate, coarse; green above, paler below, at first woolly hairy, but eventually glabrous. The central leaflet the largest, the lowermost the smallest. Leaves emerging early in spring, the leaflets at first erect, but soon deflexed on the rachis, somewhat like a half-closed umbrella: they turn yellow and brown and fall early in autumn, the leaflets disarticulating from the rachis (Fig. 4).

Venation of leaflet conspicuously strict-pinnate, with pubescence in the axils of the veins. The secondaries numerous, 12—20 or more pairs, strong, parallel and straight to the margin and there ending in teeth, as do a few branches from their outer sides. Tertiaries numerous, forming incomplete cross-ties and a fine reticulation.

B. Leaves alternate, and spirally inserted, at any rate on the erect shoots.

or (2) p. 175.]

(1) Leaves pinnate, all with a terminal odd leaflet—i.e. imparipinnate.

[In those cases where the leaflets are three only, the trifoliolate leaf is almost always pinnate, though it often appears as if built up on the palmate type: see also *Ampelopsis*, p. 175.]

(a) Leaflets three—i.e. the leaf is trifoliolate.

(i) Leaves and shoots devoid of prickles or glandular hairs: leaflets small and delicate, more or less elliptic, and silky-pubescent beneath. Plants not prostrate or scrambling.

(*a*) *Leaflets 3—8 cm. long, silky-pubescent beneath, as are also the young shoots: the latter not angular or furrowed. Stipules evident and persistent.*

Cytisus Laburnum, L. Laburnum. Small tree, with silky-pubescent young shoots, and tufts of distinctly trifoliolate leaves on long (3—4 cm.) petioles. Leaflets on short petiolules; 3—8 × 1·5—3 cm., elliptic, entire, acute or mucronate, green and glabrous above, paler and silky-pubescent beneath, and especially silvery silky when young. Stipules persistent, filamentous, small, free. Leaves opening early: autumn leaves yellow. Venation of leaflets pinnate.

(*β*) *Leaflets not more than 1—2 cm. long. Shoots angular and furrowed, glabrous. Stipules minute.*

Sarothamnus Scoparius, Koch. Broom (Fig. 34). Switch plant, with erect, angular and furrowed, glabrous shoots, bearing trifoliolate leaves below on distinct petioles, and sessile, obovate to lanceolate, entire, unifoliolate leaves above. Leaflets elliptic or obovate, silky-pubescent when young, especially beneath, then glabrescent, 10—15 × 3—6 mm., dark green. Stipules minute. Venation simple. The leaves on some branches reduced to minute scales or obsolete. Dead leaves brown.

(ii) Leaves not silky, with prickles on the petioles and ribs; leaflets large, coarse, and irregularly serrate.

(*a*) *Prickles setaceous, deflexed but unequal, and not curved and claw-like; shoots prostrate, terete, and glaucous. Leaflets pale green on both sides.*

Fig. 34. Broom, *Sarothamnus Scoparius*. 1 flowering shoot; 2 flower, p. 159 (Wo).

Rubus fruticosus, var. *Cæsius*, L. Dewberry. A variety or sub-species of the Blackberry, remarkable for its habit and the waxy bloom on the shoots, and the bristle-like prickles, &c., as well as for the prevalence of trifoliolate leaves; some leaves may, however, be 5-foliolate. Leaves about 7—17 cm.: leaflets 3—9 × 2·5—7 cm. Terminal leaflet on long petiolule, ovate or rhomboid, or

somewhat three-lobed; laterals sub-sessile, oblique, ovate, and may be somewhat bilobate; unequally and coarsely serrate. Autumn leaves purplish.

Venation pinnate with about 6 pairs of strong secondaries, nearly straight to the margin, where they end in teeth, as do also the branches given off from their outer sides. Secondaries about one-fifth the length of the midrib apart, their outer branches conspicuous. Tertiaries forming cross-ties.

(β) *Prickles on shoots and leaves usually recurved; shoots not glaucous. Leaflets dark green above and pale or white beneath, sometimes glandular.*

Rubus fruticosus, L. Though mostly 5-foliolate, there are several varieties of Bramble with trifoliolate leaves, and it frequently happens that leaves on the flowering shoots have only such. See p. 168.

[The apparently leafless Furze (*Ulex*) and the similarly spinescent Whin (*Genista*) belong to groups with typically trifoliolate leaves, and such leaves are developed on seedlings (see p. 299). The lower leaves of the Elder may also be trifoliolate.]

(b) Pinnate leaves with at least 5 leaflets.

(i) Leaves exstipulate. [For (ii) see p. 16

[Great care is sometimes necessary in deciding this point, since stipules are sometimes very minute, and often caducous, leaving scars so small as to be easily overlooked: exstipulate means that there are no stipules developed at all, but see Holly, Barberry and Mahonia.]

(*a*) *Leaves hard and very dark polished, evergreen. Leaflets about 9, and spinose-toothed. Small bush.*

Berberis Aquifolium, Ph. Mahonia. Bush with Holly-like aspect. Lower leaflets some distance up the rachis; all but the terminal one sessile. Ovate, approximate, somewhat cordate at the base, distantly spinescent serrate-dentate, with about 6—10 teeth on each side. Leaves purplish or crimson in winter. The leaf slightly sheathing, and the tip of the sheath prolonged into minute stipule-like bristle-points (see p. 281). Venation reticulate or obscurely pinnate-reticulate.

(β) *Leaves neither hard and polished nor evergreen; leaflets not spinescent-toothed. Large trees, with stout shoots and broad leaf-scars.*

* Leaflets 5—13 at most, oblong-lanceolate or oval pointed, entire or sinuate, glabrous, coriaceous and tough, fragrant. Twigs smooth: pith chambered.

Juglans regia, L. Walnut (Figs. 35, 36). Large tree, easily known by its chambered pith from all but a few allied plants. Leaves large, 20—25 cm. long, pubescent when young. Leaflets 7—9 (5—13), opposite, sub-sessile, elliptic or long-ovate; acute or shortly acuminate, entire or sinuate; smooth, usually with a few hairs in the angles of the venation, shining dark green above and paler beneath, somewhat oblique at the base, 6—10 × 3—7 cm. (5—15 × 3—9 cm., or even larger on suckers), the terminal one not articulated. Late in opening; brown in autumn. Fragrant.

Venation pinnate-looped, with numerous, often 12—14 pairs, of strong secondaries, coming off at open angles and nearly straight to the margins, there curving forward and looping into an infra-marginal vein. Tertiaries numerous and strong, coming off from the secondaries at nearly right-angles, and forming distinct cross-ties.

[The Ash differs not only in its opposite leaves and serrated margins, but in the absence of loops joining into a distinct infra-marginal vein.]

** Leaflets about 15—25; ovate-lanceolate to lanceolate, coarsely glandular-serrate at the base, but not scented. Shoots pubescent, with wide continuous pith.

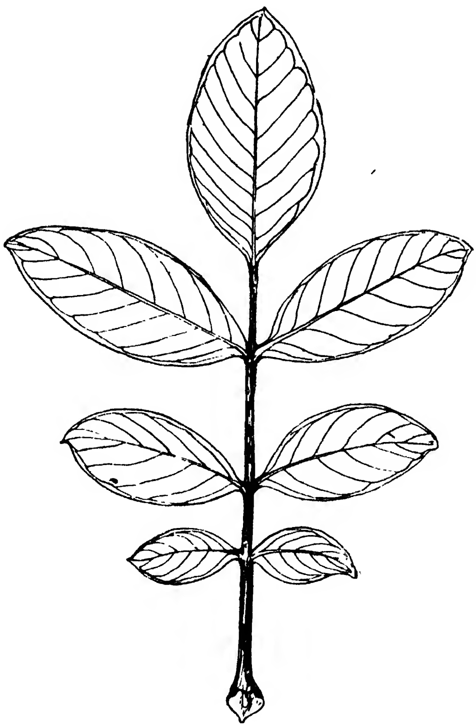

Fig. 35. Walnut, *Juglans regia*, p. 162 (D).

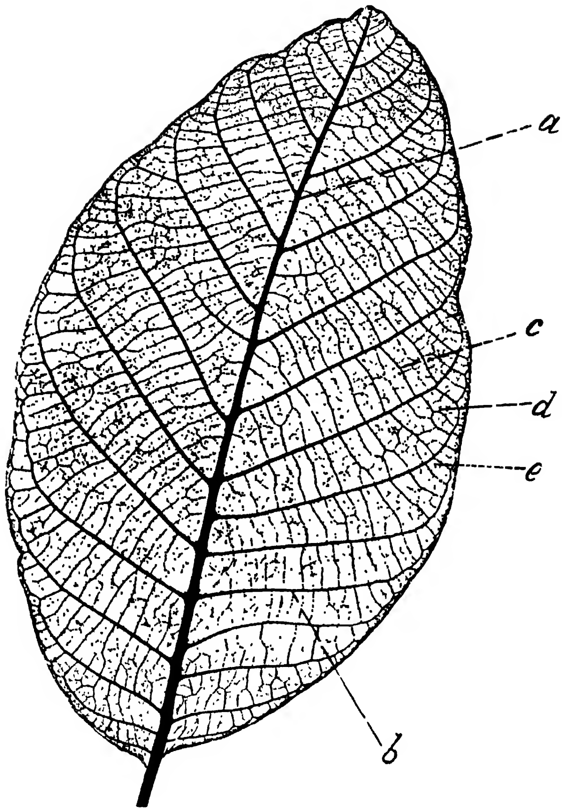

Fig. 36. Leaflet of Walnut, *Juglans regia*. Venation pinnate-looped. *a* midrib; *b* secondary; *c* tertiary, forming cross-tie; *d* shows the forward looping; *e* terminals, p. 162 (Ett).

Ailanthus glandulosa, Desf. Ailanthus, Tree of Heaven. Large tree, with the leaves sometimes enormous, up to 50—80 cm. long. The latter come out late, and are red when young: they fall with the first frosts, the leaflets

turning red and brown, and often leaving the rachis, which has a large insertion, bare on the tree for weeks. Leaflets 15—25, shortly petiolate, long ovate-lanceolate, 5—15 × 3—6 cm. in length; acuminate, entire or with one or two glandular teeth at the base, glabrous, except on the midribs below, which, like the petiolules and margin, are finely ciliate; dark green above, paler beneath. Venation pinnate-looped and reticulate.

(ii) Leaves stipulate.

[The stipules may be deciduous, or minute, and care is necessary to observe the scar, &c.; see p. 161.]

(*a*) *Stipules usually as lateral spines; buds buried in the base of petiole; leaflets* 11—25, *thin and bright green, entire.*

Robinia pseudacacia, L. False Acacia (Fig. 37). Large tree, with spreading delicate foliage, easily recognised by the usually spinose stipules and buried buds. Leaves long, 10—30 cm., rather tufted, with slender rachis and distinct pulvinus and pulvinuli. Leaflets 11—21, on short petiolules, oblong or elliptic, entire, obtuse or acute, or even slightly emarginate and mucronate; texture thin and soft, bright green, slightly glaucous and bluish below, glabrous; faintly silky-pubescent when young, 2—4 × 1—2·5 cm. Stipular spines strong, sharp and compressed, especially on the long shoots, and persistent: stipels minute, subulate, and deciduous. Autumn leaves yellow.

Venation pinnate-looped, and faintly reticulate. About half-a-dozen slender secondaries come off at open angles on either side of the midrib; they then curve forward, and loop below the margin, or fade into a delicate network. Tertiaries numerous but extremely fine, leaving the outer sides of the secondaries at acute angles and

rapidly losing themselves in the network. Secondaries about $\frac{1}{8}$—$\frac{1}{6}$ the length of the midrib apart.

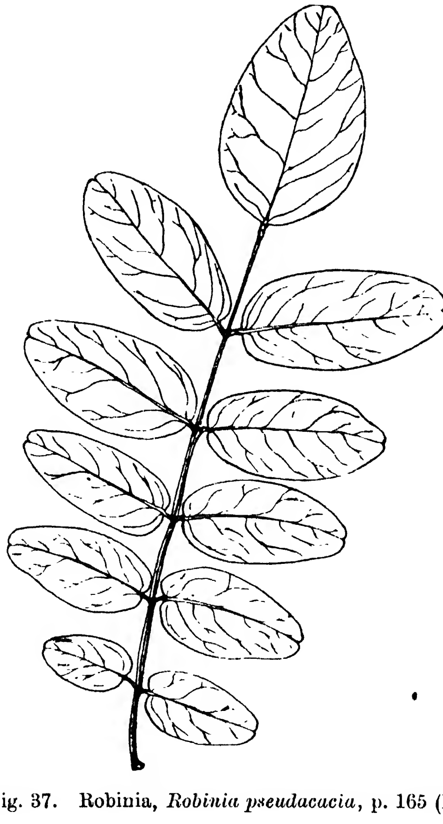

Fig. 37. Robinia, *Robinia pseudacacia*, p. 165 (D).

(β) *Stipules not spinose, and buds not buried: leaflets serrate or bi-serrate and relatively coarse.*

[If the minute bristle-points on the sheath of the leaf

of *Mahonia* are really stipules, then that species comes here. It is an evergreen with dark hard foliage, and spinescent-toothed leaflets (see p. 162).]

* Venation, petioles and shoots more or less armed with true prickles. Leaflets few, about 5—7 (3—9). Stipules more or less adnate to the petiole.

† Leaflets relatively large and broad; the whole leaf spreading, and often sub-palmate in appearance. Stipules small, subulate or linear, inserted above the base of the petiole.

⊙ *Prickles of the terete, and downy or glaucous shoots, straight and slender.*

Rubus Idæus, L. Raspberry (Fig. 38). Leaves 10—25 cm. long, trifoliolate above; the lower and those of suckers with 5 leaflets. Leaflets 9—15 cm. long, nearly glabrous above, rugose and dark green; grey- or white-tomentose or hoary beneath; ovate or elliptic, to rounded or long-ovate, the terminal one cordate at the base and on a long petiolule; the lateral sessile, soft, unequally or doubly and acutely serrate, or somewhat cut; 4—10 × 2—7 cm., oblique, not overlapping. Stipules small, filamentous or subulate, adnate half-way. Rachis prickly. Stem erect, terete and pruinose.

Venation pinnate, like that of *R. fruticosus.* Leaves purplish in autumn.

⊙⊙ *Prickles of the angular downy shoots, stout and recurved.*

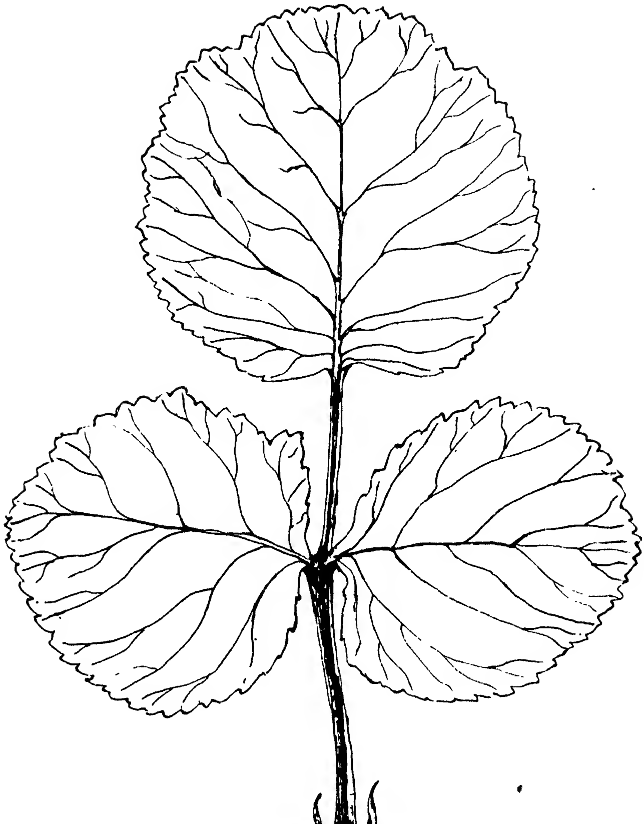

Fig. 38. Raspberry, *Rubus Idæus*, p. 167 (D).

Rubus fruticosus, L. Blackberry (Fig. 39). A scrambling shrub, usually with arched angular shoots, bearing recurved prickles, and often rooting at the tips. Leaves large and coarse, sub-evergreen, pinnately 3—5-

foliolate, the terminal leaflet usually on a longer petiolule than the others, which may be sub-sessile and overlap at the edges: often 5-foliolate on the barren shoots and 3-foliolate on those bearing flowers, but occasionally all trifoliolate, or the uppermost may be merely lobed.

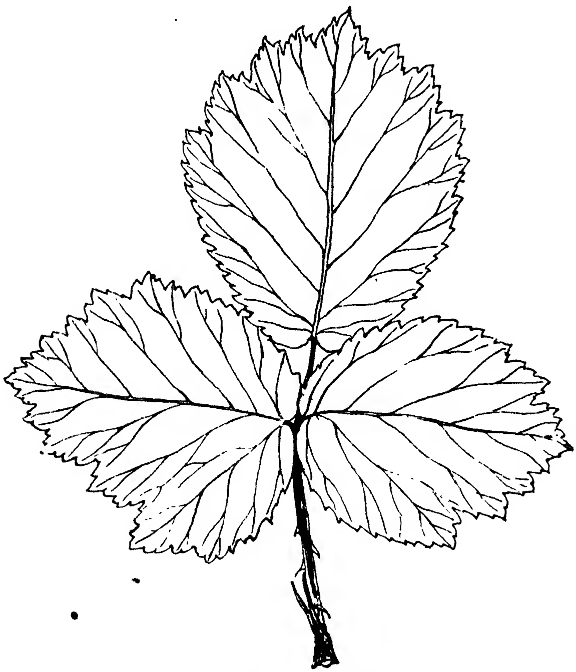

Fig. 39. Blackberry, *Rubus fruticosus*, p. 168 (D).

Leaflets obovate to rhomboid-ovate, or ovate, very variable in size; coarsely serrate or irregularly toothed; convex and dark green above, and usually glabrous; paler green or glaucous, to velvety and even tomentose white or glandular hairy beneath; or both sides may be green, or hairy. Venation pinnate and prominent below, and

bearing prickles, as also do the petioles; stipules subulate and attached some way up the petiole. Venation pinnate, as in *R. Cæsius*, p. 160. Autumn leaves usually green with purple blotches.

[The species is extremely variable, and forms numerous hybrids. As many as 45 varieties have been described for the British Flora. Of these the glaucous and trifoliolate sub-species *R. Cæsius*, L. (sp.), the Dewberry, has perhaps the best claims to be ranked separately (see p. 160), but several of the other forms are well marked by characters derived from the number of the leaflets, the glandular, hairy or glabrous under-surfaces, length of petiolules, shape of lamina, &c., the characters of the shoots—e.g. angular, bristly, prickly, or glandular, arching and rooting, &c.—and certain peculiarities of the flowers and fruit.]

†† Leaflets relatively small, the whole leaf elongated and pinnate. Stipules adnate and broad or foliaceous. Shoots cylindrical.

⊙ *Prickles stout, recurved, and more or less compressed like claws, with broad bases.*

□ *Leaflets not fragrant, nor evidently glandular on the veins; surface usually glabrous and margins serrate.*

Rosa canina, L. Dog Rose (Fig. 40). Large scrambling bush, with long arching terete shoots. Prickles equal, hooked. Leaves with 5—7 leaflets, each more or less oval or ovate, glabrous and sharply serrate; or sometimes glabrous above and downy beneath, and bi-serrate or even triply serrate. Rarely with a few inconspicuous glandular hairs on the venation. May be dark green and shining above and glaucous or matt beneath; and the terminal leaflet may be obovate. Purplish brown in autumn.

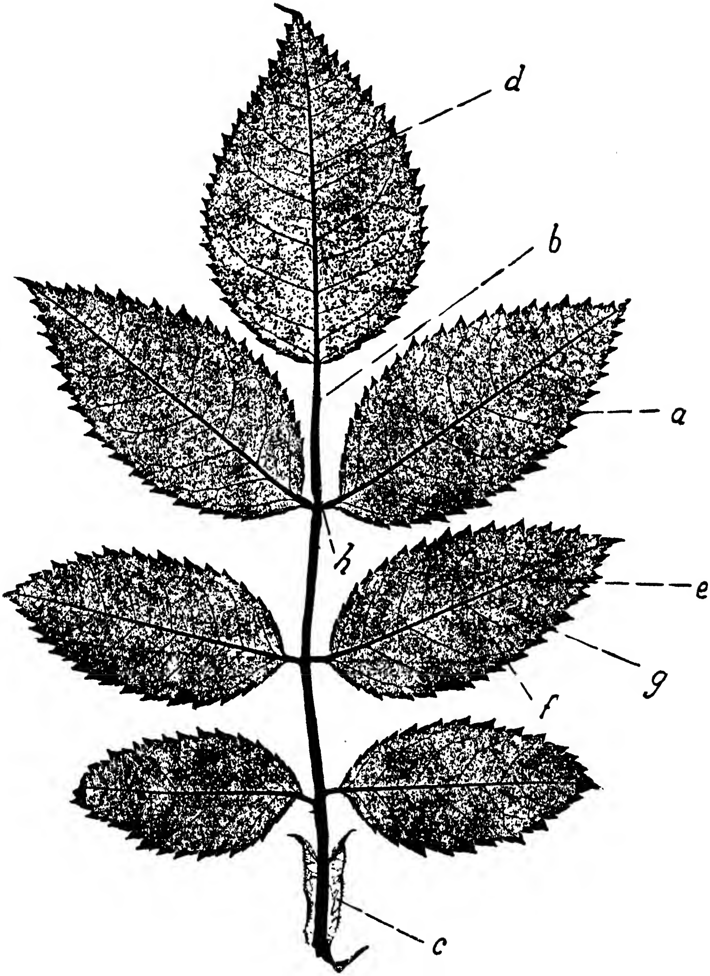

Fig. 40. Dog Rose, *Rosa canina*. Typical compound, pinnate leaf. *a* leaflet; *b* rachis; *c* adnate stipules; *d* midrib of terminal leaflet; *e* midrib of lateral leaflet; *f* secondary; *g* tertiaries and terminals; *h* petiolule of leaflet, p. 170 (Ett).

Venation pinnate-looped; about half-a-dozen fairly strong secondaries leave each side of the midrib at wide angles—about 70°—and soon curve forward, forming more or less distinct loops. Tertiaries numerous, at acute angles from the outer sides of the secondaries, and rapidly forming an extremely fine network. Secondaries about $\frac{1}{8}$—$\frac{1}{6}$ the length of the midrib apart.

[*Rosa canina* is very variable as regards pubescence, glands on the venation, bristles, and strength and curvature of prickles; the simple or double serrature and shapes of the leaflets, &c., and a number of sub-species and varieties are described.

The rule is that it is distinguished from *R. spinosissima* by the hooked prickles and large arching shoots bearing leaves with smaller and more numerous leaflets; from *R. rubiginosa* by the lack of glandular hairs on its leaf-surfaces and absence of fragrance; from *R. villosa* by the stouter curved prickles and want of distinct down; and from *R. arvensis* by its less trailing habit.]

□ □ *Leaflets fragrant, owing to numerous glandular hairs on the under-surface, bi-serrate.*

Rosa rubiginosa, L. Sweet-briar, Eglantine. Tufted bush, the shoots often rusty from the crowded glandular hairs. Leaflets small, oval or sub-orbicular, with rounded base, acute or obtuse, shining above. Bristles and glandular hairs often intermingled with the hooked prickles. Venation as in *R. canina*; leaves purplish brown in autumn.

⊙ ⊙ *Prickles slender and straight, setaceous, not dilated below.*

□ *Leaflets* 7—9, *small, elliptic or rounded, obtuse, serrate, glabrous and eglandular, or nearly so. Prickles very unequal.*

Rosa pimpinellifolia, L. Burnet Rose. A small bushy shrub, usually in sandy soil, near the sea. There may be a few glandular hairs on the shoots intermingled with the setaceous prickles. The leaflets usually relatively broad and occasionally bi-serrate. Several varieties occur, differing in pubescence, glands, &c. Venation as in *R. canina*. Purple brown in autumn.

□□ *Leaflets* 5—7, *greyish and downy, oblong or elliptical, bi-serrate. Prickles equal.*

Rosa villosa, L. Downy Rose. Large bush with arching branches, and leaves hairy on both sides. The prickles are more equal than in *R. pimpinellifolia*, the leaflets larger and more bi-serrate, and the lower surface may be tomentose. But here again the pubescence and glands, serration and prickles vary much. Venation as in *R. canina*. Purple brown in autumn.

** Shoots and foliage devoid of prickles or spines; stipules free and deciduous; leaflets numerous, about 11—19, oblong-acute, serrate, base entire.

† Leaflets sharply serrate nearly the whole way up. Buds black and grey pubescent. Stipules linear and caducous.

Pyrus Aucuparia, Gaertn. Mountain Ash, Rowan (Fig. 41). Medium-sized tree, with velvety black and grey buds, and long pinnate leaves, 15—25 cm. Leaflets 11—19, laterals sessile, the terminal on a distinct stalk, 3—6 × 1—1·5 cm., lanceolate, narrow oblong, or linear-oblong; sub-acute, serrate or bi-serrate, except at the extreme base, glabrous and somewhat shining dark green above, glaucous or slightly pubescent beneath, or hairy on

the venation. Rachis pubescent, becoming glabrous. Autumn leaves yellowish, red, or brown. Venation as in *P. Sorbus.*

†† Leaflets cuspidate-serrate along the upper half or two-thirds only. Buds glabrous and viscous. Stipules semi-lunate, deciduous.

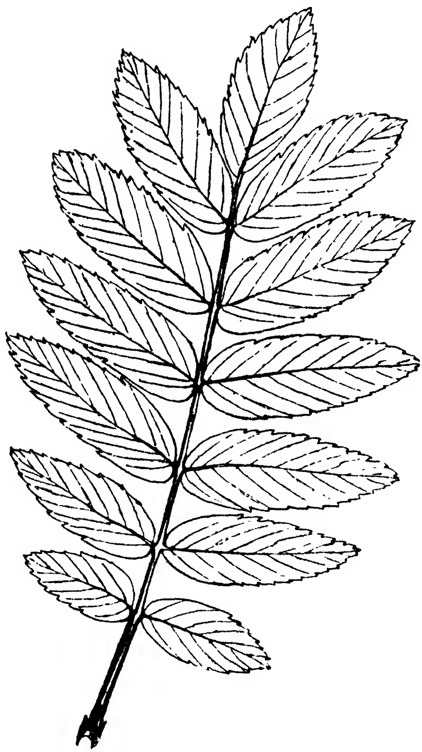

Fig. 41. Rowan, *Pyrus Aucuparia*, p. 173 (D).

Pyrus Sorbus, Gaertn. Service Tree. Much like *P. Aucuparia,* to which it is closely allied, but differs in fruit,

larger leaves, and the leaflets are more sharply serrate and entire along the lower third, and bluish green below. Leaflets about 13—17 (11—19), oblong-acute, very acuminate, sharply cuspidate-serrate at the upper two-thirds, the laterals sessile; tomentose beneath when young, becoming glabrous, matt and paler beneath. Buds glabrous and viscous. Autumn leaves yellow to purple browns.

Venation of leaflets pinnate, with close and rather fine secondaries coming off at acute angles and slightly curving forwards; branching, and tending to break up at the margins, with slight looping and numerous fine branches before ending in the teeth.

[*Pyrus Aria* sometimes has the leaves pinnate at the base (see p. 253).]

(2) Leaves palmate, digitately 5-foliolate, exstipulate, with tendrils opposed to some of them.

Ampelopsis hederacea, Mchx. Virginian Creeper (Fig. 42). Tendril climber, the digitate foliage brilliant crimson and scarlet in autumn. Leaflets 5, or sometimes 3, ovate-lanceolate, ovate, oblong, or obovate and often unequal; coarsely mucronate-serrate, except at the entire base, on short petiolules, apex slightly acuminate. Glabrous and shining. Leaflets 3—12 × 2—5 cm.

Leaves turning all shades of purple and yellow reds, to scarlet and crimson, in autumn.

Venation pinnate, the midrib stout below and thinning out above, somewhat sinuous. Secondaries strong, at angles of 45—60°, about $\frac{1}{5}$ the length of the midrib apart, branching and forking as they approach the margin, and showing some loops, ultimately branching into the teeth. Tertiaries leaving the secondaries at acute angles outside,

obtuse inside, and forming cross-ties. Meshes large, irregular and angular.

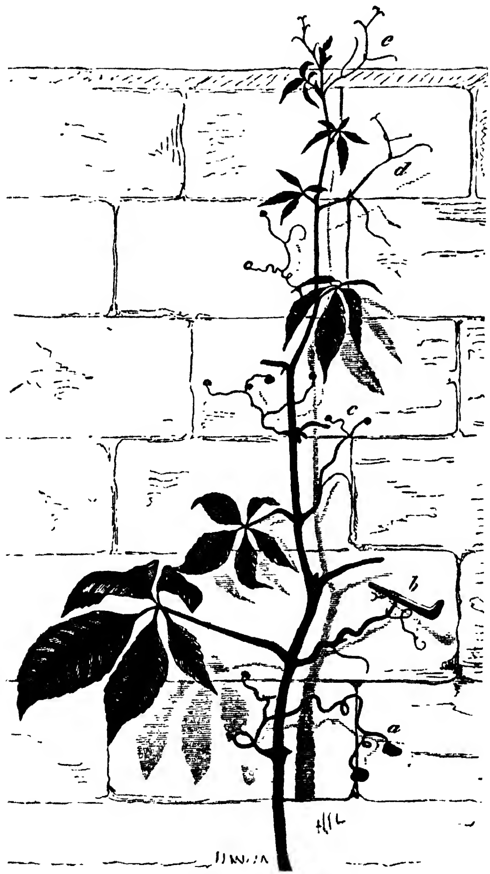

Fig. 42. Shoot of *Ampelopsis*, Virginian Creeper, climbing by means of branch-tendrils, some of which twine round nails, &c. (*b*), others fasten their tips to the bricks by means of sucker-like dilations (*a* and *c*); *d* and *e*=young tendrils, p. 175 (Sa).

II. LEAVES SIMPLE: ENTIRE, TOOTHED OR LOBED, BUT IN THE LATTER CASE THE DIVISIONS NEVER EXTEND QUITE TO THE MIDRIB.

A. LEAVES OPPOSITE, OR RARELY IN WHORLS OF THREE OR FOUR.

[For B p. 203

(1) Leaves stipulate.

[For (2) see p. 1

[See note, p. 161.]

(a) Leaves broad ovate-rhomboid, 3—5 palmately lobed; with sessile glands on the top of the petiole, and linear fringe-like stipules below.

Viburnum Opulus, L. Guelder Rose (Fig. 43). Glabrous shrub. Leaves about 6—9 × 5—8 cm. or sometimes larger, rounded ovate and tri-lobed, palmatifid; the lobes large, triangular or triangular-ovate, and curved outwards, acute or acuminate, and coarsely and unequally sharply toothed, or again slightly lobed; base of lamina rounded and entire, or slightly cordate, or sinuous. Thin, green and quite glabrous above, paler and sparsely pubescent below; downy when young. Petioles about 2 cm. long and slender, their glands reniform or cupular and often reddish; stipules herbaceous, narrow and accompanied by two stalked glands. Autumn leaves with pink and crimson coloration.

Venation palmate or pseudo-palmate, the three or more primaries often starting at different levels, all ending in the points of the lobes, and giving off numerous secondaries in pinnate order, each of which runs nearly to the margin and then breaks up, often forking, just beneath. Tertiaries forming more or less complete cross-ties. Outer branches of laterals conspicuous and regular.

(b) Leaves not lobed; ovate or lanceolate, glabrous and matt green, serrulate; petioles eglandular, stipules very minute or half-ovate, caducous or obsolete.

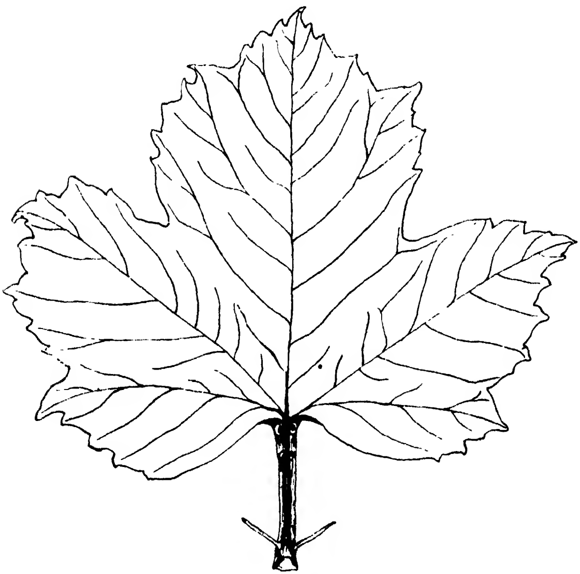

Fig. 43. Guelder Rose, *Viburnum Opulus*, p. 177 (D).

(i) Leaves lanceolate or obovate-lanceolate, at least 4—5 times as long as broad stipules half-ovate, but rarely seen.

Salix purpurea, L. Purple Willow (Fig. 44). Shrub with sub-opposite leaves. Leaves thin, about 9—11 (9—18) cm. long, oblong-obovate to obovate-lanceolate, or oblong to nearly linear lanceolate; sub-sessile and often opposite, 4—6 times as long as broad, the greatest

breadth usually about the upper third. Suddenly and shortly acuminate. Entire at the base; serratulate along the upper two-thirds, teeth non-glandular, unequally

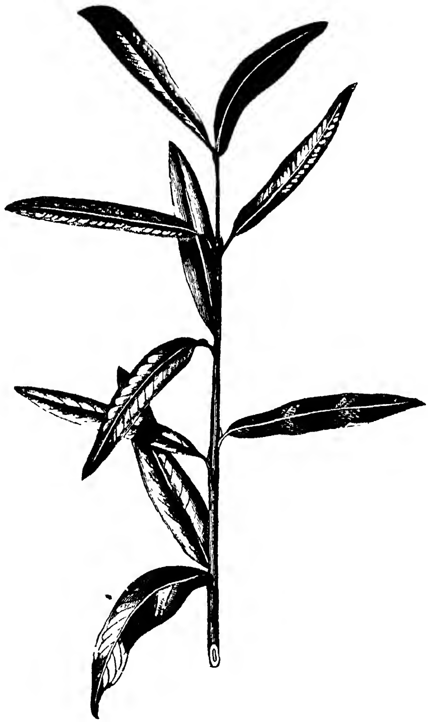

Fig. 44. Purple Willow, *Salix purpurea*, p. 178 (Sc).

distant. Plane, glabrous, or thick and tough and with a few scattered silky caducous hairs; shining green above, glaucous and with bluish bloom beneath. Shortly petiolate; stipules often absent, half-ovate. Leaves slightly

pubescent when young; black on drying. See p. 293. Autumn leaves brown to black.

Venation like that of *S. alba*, pinnate-reticulate, but the secondaries much finer and closer. Stomata on both surfaces; those above isolated or numerous.

[For the hybrid *S. rubra* see p. 245.]

(ii) Leaves ovate or oblong lanceolate, about twice as long as broad: stipules minute and very caducous.

Euonymus europæus, L. Spindle Tree (Fig. 45). Glabrous shrub, with fœtid odour and angular shoots and twigs; the stipules so minute and caducous as to be easily overlooked. Leaves shortly petiolate, 3—12 × 1·5—4 cm., elliptic, or oblong-lanceolate to lanceolate, or ovate; acute or acuminate, finely serratulate, glabrous and matt green, paler beneath; petiole 5—10 mm. Autumn leaves reddish.

Venation pinnate-looped. The midrib gives off about 8 pairs of secondaries, pinnate at open angles, slender and slightly curved forwards; these soon loop, and from the loops the ends of small terminals pass into the teeth. Reticulation open and faint. Secondaries about $\frac{1}{8}$ the length of the midrib apart, with no prominent outer branches. Tertiaries at very acute angles on the outer, obtuse on the inner side of the secondaries.

(2) Leaves exstipulate.

[See note, p. 161.]

[For (b) see p. 186.]

(a) Leaves lobed, palmatifid, and with palmate venation. Petioles long.

[For (ii) see p. 184.]

(i) Leaves large, up to 10—20 cm. or more in diameter.

Fig. 45. Spindle Tree, *Euonymus europæus*, p. 180 (Wi).

(*a*) *Lobes more or less ovate, the sinus between any two narrow and acute; coarsely and irregularly cut into blunt teeth or lobules, apex bluntly acuminate; sap watery.*

Acer pseudoplatanus, L. Sycamore (Fig. 46). Large tree with leaves 10—15 or even 20 (9—16 × 10—21) cm. diameter, not milky, pentagonal and 5-lobed; lobes more

or less ovate, the lowest much smaller, and the sinus very narrow and acute, and extending about half-way to the midrib. Lobes coarsely and irregularly bluntly serrate, crenate-serrate, or slightly lobed, the apex more or less

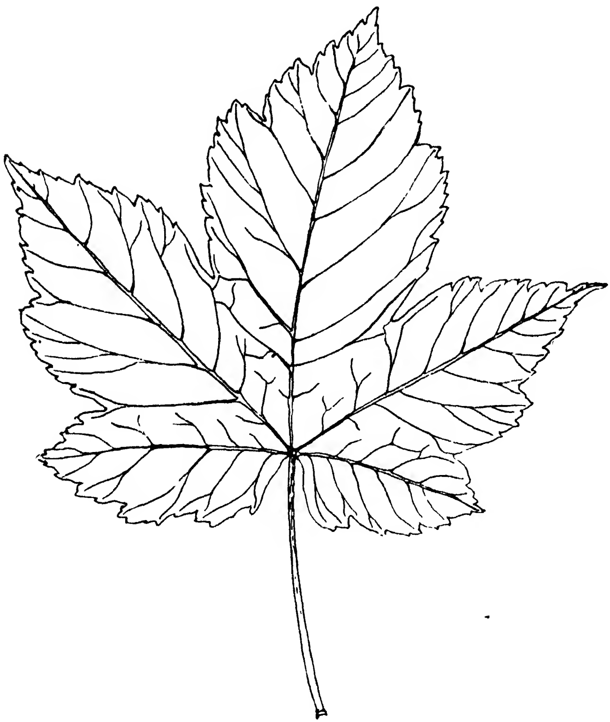

Fig. 46. Sycamore, *Acer pseudoplatanus*, p. 181 (D).

acute or bluntly acuminate; lateral lobes larger than basal; base cordate. Surface glabrous, somewhat wrinkled; dark green and shining above, paler matt green and glaucous,

or sometimes purplish red beneath, and with hairs on the principal ribs; petiole firm, but slender, about 10—20 cm. long, green or red. Leaves densely pubescent beneath when young; brown in autumn, and often disfigured by black blotches, due to the parasitic fungus *Rhytisma.*

Venation palmate, of 5 primaries, ending in the points of the lobes; secondaries pinnate and ending in lobules or teeth, numerous, slightly curved forwards. Tertiaries well developed and rapidly breaking into a fine meshwork. Secondaries on the midrib about $\frac{1}{8}$ its length apart.

(β) *Lobes angular, the apex and teeth drawn out into long acuminate points, the sinus wide and hardly acute. Latex white.*

Acer platanoides, L. Norway Maple (Fig. 47). Large tree, with thin, herbaceous, glabrous leaves, 5—15 × 8—25 cm., almost plane, and with the tips of the lobes and teeth drawn out into filiform points. Leaf rounded, with cordate base, bright green on both surfaces, and glabrous; or pubescent on the venation beneath. The 5—7 lobes and the teeth triangular; or the larger lobes with nearly parallel sides, and separated by a rounded scallop-like or wide and scarcely acute sinus, extending not more than a third of the way in. Petiole about 5—20 cm. long and slender, devoid of a tuft of hairs where it joins the lamina, often red. Spring foliage greenish yellow: autumn leaves fine yellow.

Venation palmate, like *A. pseudoplatanus*, but the sinus between the lobes much more open, and the lobes and teeth more triangular and prolonged into slender points. The secondaries on the midrib about $\frac{1}{6}$ the length of the latter apart.

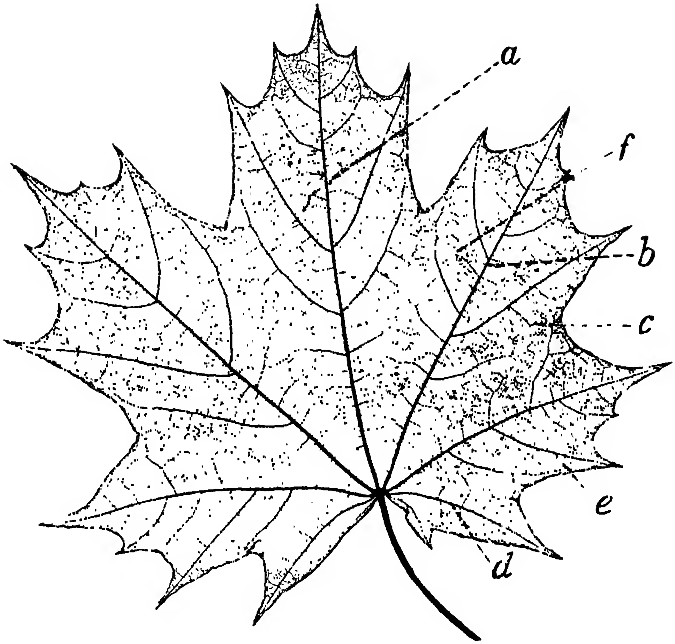

Fig. 47. Norway Maple, *Acer platanoides*. Typical palmate venation. *a* midrib, which comes off with the other, radiating, primaries *b* and *d* from a single point at the base; *c* tertiaries and terminals forming network; *d* basal primary; *e* secondary; *f* tertiary, p. 183 (Ett).

(ii) Leaves small, usually not more than about 6—8 cm. in diameter, but may reach 10 or 12 cm.; pubescent below. Latex white.

Acer campestre, L. Maple (Fig. 48). Small tree, often with very corky twigs and branches. Leaves 3—7 × 4—10 cm., thin, not wrinkled and rather firm, more or less pentagonal, cordate at the base; with 3—5 somewhat broad obtuse lobes, the lower much smaller, each slightly cut into

further shallow rounded lobes or large teeth, or sinuate, and separated by deep angular sinuses, extending about half-way in. Young leaves pubescent; the older glabrous, or pubescent beneath, especially on the venation, green and

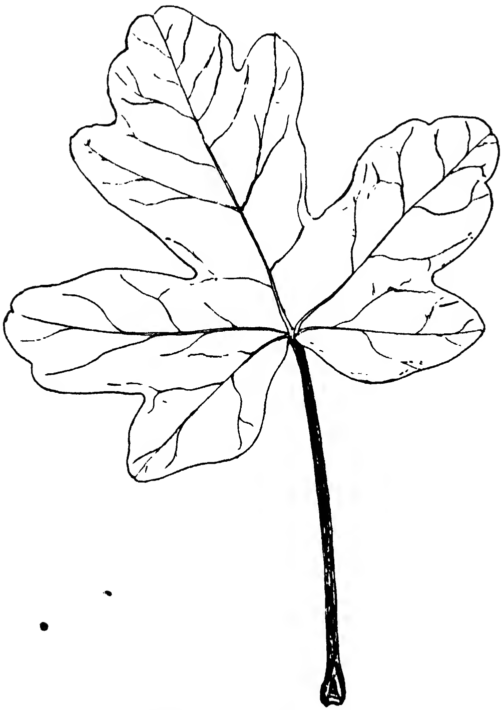

Fig. 48. Maple, *Acer campestre*, p. 184 (D).

somewhat shining above, paler beneath. Petioles often red, 3—4 (2—8) cm. long, slender, pubescent: latex white. The three larger lobes entire towards their bases, but each cut into about 3 lobules, and bluntly crenate or toothed

above. Leaves fine yellow in autumn, often disfigured by black blotches due to the fungus *Rhytisma*.

Venation palmate and like that of *A. pseudoplatanus*, but the secondaries on the midrib about $\frac{1}{5}$—$\frac{1}{3}$ the length of the latter apart.

[Hartig pointed out that the leaves of *A. pseudoplatanus* and *A. platanoides* have a tuft of hairs at the junction of the lamina and petiole; and that *A. campestre* and *A. pseudoplatanus* bear small shortly-stalked capitate glands on the upper surface of the primary veins, which catch dust, pollen, &c.

Acer pseudoplatanus is easily distinguished from *A. platanoides* by the blunter and more rounded lobes, the sinus deep and acute, and the want of milky juice; from *A. campestre* by the much larger size, narrower sinus, and the pubescence. *Acer platanoides* differs from the Plane (p. 230) not only in having opposite leaves, but also in its venation and its lack of stellate hairs; its buds are also not buried, and the base of the petiole not hollowed into a cup.]

(b) Leaves not lobed, at most sinuate or toothed.

[For (ii) see p. 190.]

(i) Margins of leaf serrate or dentate.

(*a*) *Leaves large, lanceolate, polished, evergreen coriaceous.*

Aucuba japonica, Thunb. Aucuba (Fig. 49). Evergreen shrub, with opposite, petiolate, exstipulate, coriaceous, shining green leaves. Lamina ovate-lanceolate acuminate, coarsely serrate; petiole dilated below, articulated. The leaves are often variegated with yellow blotches. Dead leaves brown. Often called Laurel, but has nothing in common with either the true Laurels (*Laurus*) or the Cherry Laurel (*Prunus*).

Venation pinnate with a tendency to loop, and soon breaking into a network obscure above. Midrib prominent below.

Fig. 49. Aucuba, *Aucuba japonica*, p. 186 (E & P).

(β) *Leaves ovate or elliptic, not polished or evergreen, nor coriaceous.*

* Leaves and shoots greyish mealy with stellate hairs; margins dentate-serrate. Venation pinnate with numerous forked secondaries.

Viburnum Lantana, L. Wayfaring Tree (Fig. 50). Shrub with scurfy or mealy shoots and foliage. Leaves large and thick, 6—15 × 4—9 cm., ovate or oval, acute or rather obtuse, base rounded or cordate, often oblique; finely dentate-serrate, dark green, rugose, plaited, with more or less appressed and mostly simple hairs above, giving a soft and velvety appearance; greyish with stellate hairs beneath, especially abundant on the venation, looking like mealy or scurfy whitish down. Petiole short

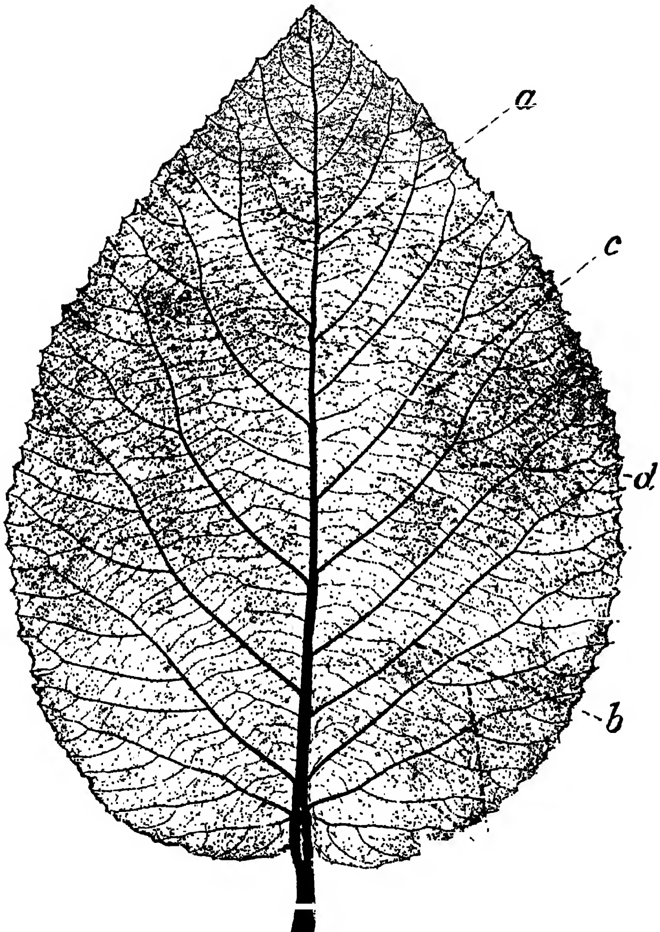

Fig. 50. Wayfaring Tree, *Viburnum Lantana*. Typical simple leaf, with pinnate venation. *a* midrib; *b* secondary; *c* tertiaries forming cross-ties; *d* terminals; *e* outer branches of secondaries forking to the edges, p. 187 (Ett).

(1—1·5 cm.), exstipulate, eglandular, covered with stellate hairs. Autumn leaves deep red.

Venation pinnate, close. Midrib prominent beneath, thinning out above, nearly straight; the secondaries more or less sinuate, running to the margin and ending there, at angles of 40—50°, but forking before they reach it; strong, the ends of the forks and their branches ending in the dentate teeth: the forked branches almost all from the outer sides, and more numerous from the lower secondaries, each of which gives off about 5 very distinct forked branches from its outer side. Tertiaries fine, simple, linking or looping the ends of the forks, and forming cross-ties between the secondaries. Secondaries about $\frac{1}{10}$—$\frac{1}{8}$ the length of the midrib apart, closer below than above. Meshes rectangular.

** Leaves glabrous or nearly so, matt green, finely serrate. Venation pinnate with few arched secondaries.

Rhamnus catharticus, L. Buckthorn (Figs. 51, 52). Shrub with thorns. The leaves are not always opposite, and are tufted on the dwarf shoots; but the sub-opposite arrangement prevails on the long shoots. Young petioles and leaves pubescent on the lower side. Leaf 3—6 × 1·5—3 cm., on a short petiole (5—15 mm.), ovate, obovate or elliptic, shortly acuminate; rounded or flattish or slightly cordate at the base; finely and regularly serrate; dark green and glabrous above, paler and slightly pubescent on the venation beneath. Stipules subulate, caducous, about $\frac{1}{3}$—$\frac{1}{2}$ as long as the petiole. Leaves in autumn yellowish green.

Venation pinnate-arcuate. The midrib gives off about 3 strong secondaries at sharp angles on each side from its lower half; these curve forwards in arches and converge

towards the apex, but there break up, without forming loops, and disappear before reaching the margin. Tertiaries numerous and much finer. Upper and middle secondaries much further apart than the middle and lower ones, and converging into the apical region.

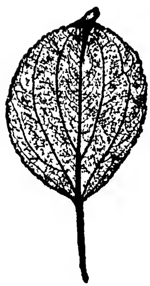

Fig. 51. Buckthorn, *Rhamnus catharticus*, p. 189 (Ett).

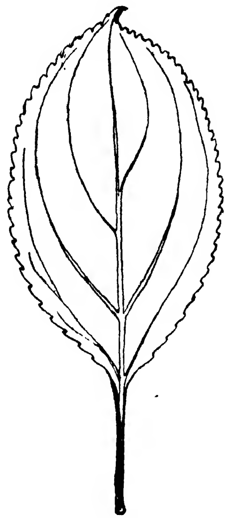

Fig. 52. Buckthorn, *Rhamnus catharticus*, p. 189 (D).

[The Spindle Tree (*Euonymus*) may also be sought for here if the stipules are overlooked (see p. 180), but the secondaries are more numerous and looped.]

(ii) Margins of leaf entire, or at most inconspicuously sinuate, or with microscopic serrulation.

(*a*) *Leaves small or minute, scale-like, linear, acicular, or subulate, with no distinct venation except the midrib, evergreen.*

* Leaves in whorls of three or four.

† Leaves subulate, pungent, spreading, hard and rigid; in whorls of three; margins not revolute, and no groove beneath. Erect resinous shrub.

Juniperus communis, L. Juniper. Tufted bush. Leaves crowded, subulate, linear-lanceolate, narrowed at the base, straight, and sharp, prickle-pointed, spreading in whorls of 3; about 1—2 or even 3 cm. long, and 1—2 mm. broad, the lower shorter, bright green beneath, glaucous and channelled above, with one or two silvery lines; margin and midrib prominent. Venation simple and obscure. The leaves persist about 4 years: reddish in winter. Stomata on upper surface. One central resin-canal immediately beneath the axial vascular bundle. Vascular bundle undivided. Endodermis poorly developed.

†† Leaves not rigid and pungent; but narrow linear, &c., with revolute margins and grooved beneath; low sub-shrubs, not resinous.

⊙ *Shoots and leaves glabrous.*

▱ *Leaves acute, in whorls of* 3, *rarely of* 4, *with numerous short axillary tufts; minutely serrulate at the margins.*

Erica cinerea, L. Bell Heather. Leaves small; 5—8 × 0·5—1·5 mm., and crowded, with numerous short axillary tufts; in whorls of 3, or rarely of 4, narrow linear, acute, glabrous, with cartilaginous whitish margins, dark shining green, and minutely serrulate, plane above, with a median longitudinal fine rill and keel beneath. Red-brown in autumn.

▱▱ *Leaves obtuse, in whorls of* 3 *or* 4 *or crowded and alternate at the tips of the shoots.*

Empetrum nigrum, L. Crowberry. Leaves evergreen, numerous, small, sub-sessile, in whorls of 3 or 4; or, at the tips of the shoots, spirally imbricate and crowded; linear, linear-oblong, or acicular, blunt, semi-terete, 4—5 × 1 mm.; margin revolute, glabrous or slightly ciliate; leathery, shining green above; paler, with a whitish midrib beneath. Red-brown in autumn.

⊙ ⊙ *Shoots and leaves downy; the latter hardly acute, and in whorls of* 4, *rarely of* 3.

Erica tetralix, L. Cross-leaved Heath. Leaves in whorls of 4, rarely of 3, acicular or linear-lanceolate, hardly acute, 4—5 × 0·5—1 mm.; margins revolute, ciliate with stiff glandular hairs, pubescent, dark green above, bluish-glaucous beneath, the concave area tapering, and the midrib downy. Red-brown in autumn.

[The rare species *Erica ciliaris*, with broader, almost ovate, gland-ciliate leaves, *E. vagans*, with linear pointed leaves, and *E. carnea* with linear blunt leaves may also be mentioned.]

** Leaves opposite and decussate, not normally in whorls of three; fleshy and scale-like, short and blunt, or at least not rigid and pungent.

† Shoots with crowded leaves and flattened.

Thuja gigantea, Nutt. Arbor Vitæ. Tall tree, with flattened shoots of crowded, decussate, sessile and fused, ovate or deltoid, acuminate, scale-like, but bright green leaves, glandular on the back; or smaller, apiculate and almost devoid of glands. Venation obsolete. Leaves reddish in winter.

†† Shoots of crowded leaves quadrangular, not flattened.

⊙ *Leaves not revolute or grooved beneath; glandular on the back. Resinous tree.*

Cupressus sempervirens, L. Cypress. Conical tree, with scale-like leaves, crowded and sessile in four ranks; some broad-ovate or obovate-oblong, obtuse or mucronate and fused below, but most of them short, scale-like, rhomboid-oblong, or ovate-rhomboid, about 1 mm. long, with a gland on the dorsal surface, grey-green. Venation obsolete. Stomata on upper surfaces only. Leaf reddish in winter.

⊙⊙ *Leaves revolute and grooved beneath; no dorsal gland. Non-resinous sub-shrub.*

Calluna vulgaris, Salisb. Ling. Leaves very short and small, opposite and decussate, sessile, slightly auriculate or spurred at the base, and closely imbricate; linear or linear-lanceolate, obtuse, 2—3 × 0·3—1 mm., convex above, slightly grooved beneath, shining green and glabrous or glabrescent. Red-brown in autumn.

(β) *Leaves not scale-like or subulate, but exposing distinct surfaces and with more or less evident venation.*

* Leaves fleshy or leathery and thick; venation poor after the secondaries. Evergreen.

† Leaves narrow-oblong to obovate-lanceolate, 3—9 cm. long, obtuse: opposite or exceptionally in whorls of 3. Yellowish green, and somewhat fleshy.

Viscum album, L. Mistletoe (Fig. 53). Rounded bush with dichotomous shoots, yellowish green, and parasitic on various trees. Leaves 3—4 cm. × 10—15 mm.,

thick and fleshy or coriaceous, glabrous, persistent, sub-sessile, green or yellowish green, oblong to nearly obovate

Fig. 53. Mistletoe, *Viscum album*, p. 193 (Wo).

entire, obtuse, narrowed at the base, and articulated. Venation of 5—7 veins. Dead leaves yellow.

†† Leaves more or less oval, not more than 2—3 cm. long, dark green, hard and dry, occasionally sub-opposite.

⊙ *Leaves* 20—30 × 10—16 *mm., margins not revolute; erect shrub.*

Buxus sempervirens, L. Box (Fig. 54). Evergreen shrub with disagreeable odour, and hard dark crowded foliage. Leaves sub-sessile, ovate, elliptic or oblong, 2—3 cm. × 10—16 mm., entire, glabrous, deep polished green above, paler and matt green beneath, obtuse or retuse, rarely acute. Venation pinnate, but the numerous straight and parallel secondaries, simple or forked, soon lost and obscure. Dead leaves brown.

[The leaves of some of the dwarf Whortleberries, &c.—

e.g. the Cowberry and Bearberry—are Box-like, but alternate; see pp. 301 and 302.]

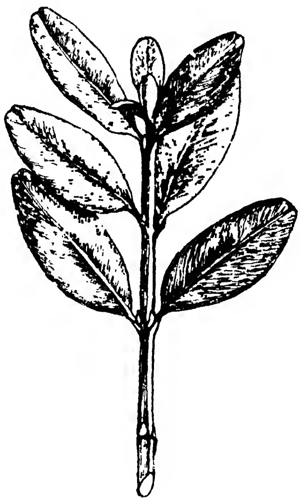

Fig. 54. Box, *Buxus sempervirens*, p. 194 (D).

⊙⊙ *Leaves 5—8 × 2—3 mm., margins strongly revolute; prostrate sub-shrub.*

Loiseleuria procumbens, Desv. Creeping Azalea. Leaves small, opposite, coriaceous, thick, numerous, evergreen, 5—8 × 2—3 mm.; ovate, elliptic-ovate, or oblong, obtuse, shining above, convex and grooved; edges revolute, midrib prominent and pale in the groove beneath. Petiole distinct, 2—3 mm. Red-brown in autumn.

** Leaves thin and herbaceous, with well-developed venation.

† Venation pinnate-arcuate, the secondaries few, originating in the lower half of the midrib and curving and converging towards the apex.

Cornus sanguinea, L. Dogwood, Cornel (Fig. 55). Shrub with blood-red autumn and winter twigs. Leaves ovate, broad-ovate, elliptic, or ovate-oblong acute, about

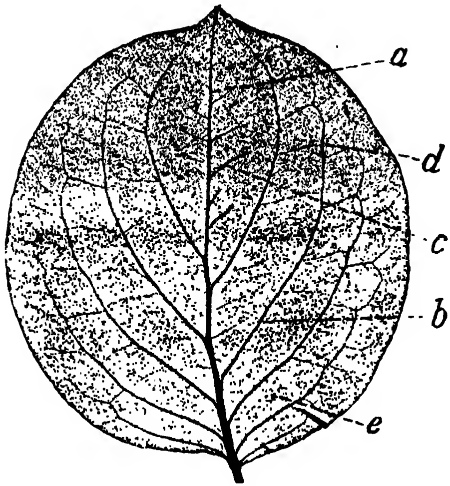

Fig. 55. Dogwood, *Cornus sanguinea.* Venation pinnate-arcuate. *a* midrib; *b* secondary, arching forward and losing itself in the leaf near *d*; *c* intercostal; *e* terminals (Ett).

6—10 cm. long, shortly petioled, green and glabrescent on both sides, but hoary or silky when young Varying in size from 4—8 × 3—5 cm., or even larger on suckers, the lower on a shoot the smaller; petiole 3—10 mm. Leaves blood-red in autumn.

Venation pinnate-arcuate, somewhat as in *Rhamnus catharticus.* The midrib gives off about 4—5 strong, much-curved secondaries from its lower half on each side, which converge forwards in arches into the apical region, but break up before reaching the margins. Tertiaries very minute and obscure. The secondaries show some tendency

to loop near the margins, and the upper are more distant than the lower.

†† Venation not arcuate, but pinnate-reticulate or looped, the secondaries equidistant along the midrib, and soon breaking up into reticulations or looping forwards.

⊙ *Leaves velvety-pubescent on both sides, ovate or obovate, petiolate.*

Lonicera Xylosteum, L. Fly Honeysuckle (Fig. 56). Erect shrub, not twining. Leaves dark green above, soft and velvety, especially on the paler grey-green under-

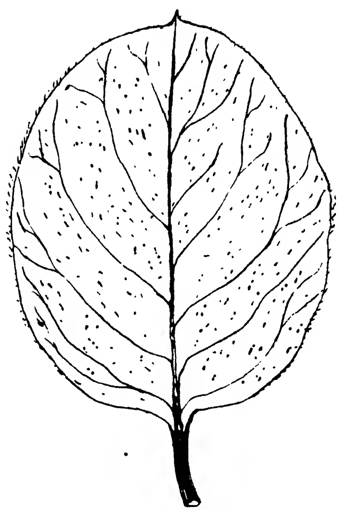

Fig. 56. Fly Honeysuckle, *Lonicera Xylosteum*, p. 197 (D).

surface, 3—9 × 2—3 cm., shortly petiolate (2—5 mm.), elliptic, or ovate to obovate with rounded base, acute or

sub-mucronate. Venation as in *L. Caprifolium.* Old leaves brown.

⊙ ⊙ *Leaves glabrous, at least above.*

▱ *Leaves broad and heart-shaped, acuminate, on distinct petioles.*

Syringa vulgaris, L. Lilac (Fig. 57). Bush with

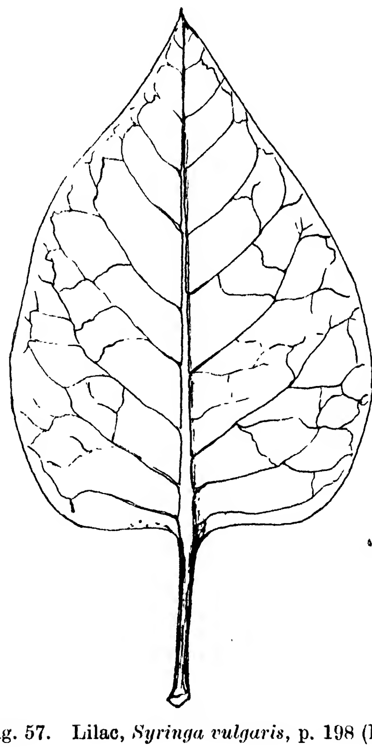

Fig. 57. Lilac, *Syringa vulgaris*, p. 198 (D).

falsely dichotomous shoots, and leaves more or less heart-shaped, ovate, or orbicular-ovate, 5—10 × 5—7 cm.;

acuminate, entire, thin, glabrous; green both sides but paler below. Petiole long, 15—25 mm. Autumn leaves brown.

Venation pinnate-reticulate, with a tendency to looping.

□ □ *Leaves sessile, or sub-sessile on very short petioles; the base not cordate.*

§ *Leaves not narrowed and tapering below; the upper broad and quite sessile, or connate.*

♯ *Upper leaves of flowering shoots connate round the stem.*

Lonicera Caprifolium, L. Perfoliate Honeysuckle (Fig. 58). Twining shrub. Leaves elliptic-rounded, broadly oblong, ovate, or obovate, hardly acute, glabrous; whitish or glaucous beneath, 4—6 cm. long (3—9 × 3—4 cm.), darker above. The lowest and those on the sterile shoots short and narrowed into a petiole, those beneath the inflorescences sessile and the uppermost connate into a single sub-orbicular oval or sub-rhomboid perfoliate leaf-pair. Autumn leaves brown.

Venation pinnate-looped, the secondaries sinuous and strongly curving forwards, forming loops some distance beneath the entire margin: superposed on these the tertiaries form about two series of further loops, convex to the margin. Tertiaries numerous and forming irregular cross-ties and distinct meshes between secondaries.

♯♯ *Upper leaves of flowering shoots sessile, but not connate.*

Lonicera Periclymenum, L. Honeysuckle. Twiner. Leaves ovate or oblong or more or less elliptic, acute, 3—7 cm. long (5—9 × 2—5), all shortly petiolate (2—3 mm.) or sub-sessile, except those under the inflorescences, which are rounded and quite sessile, but not connate;

glabrous above, glaucous beneath or with traces of down, thin dark green, or brownish beneath. Entire or faintly

Fig. 58. Perfoliate Honeysuckle, *Lonicera Caprifolium*, p. 199 (Wo).

sinuate lobed. Venation like that of *L. Caprifolium*. Autumn leaves brown.

§§ *Leaves tapering below into a very short petiole; the upper not broad or connate.*

♯ *Leaves lanceolate, or elliptic-lanceolate; sub-evergreen, rather thick and tough.*

Ligustrum vulgare, L. Privet (Figs. 59, 60). Leaves oblong-lanceolate or elliptic-lanceolate, entire, acute, green

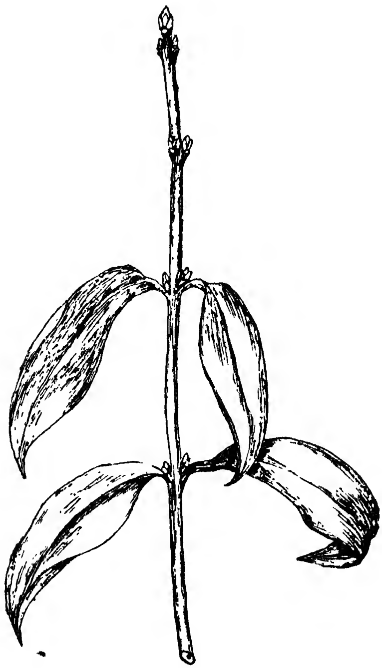

Fig. 59. Privet, *Ligustrum vulgare*, p. 201 (D).

and quite glabrous, 3—6 cm. long (3—8 × 1·5—3), shortly petiolate, 3—5 mm.

Venation pinnate-reticulate, the few weak secondaries slightly sinuous and curved forwards, slightly arched and looped, and rapidly vanishing into an obscure network or tending to loop below the margin. Tertiaries sparse and weak.

The leaves are sub-evergreen, turning purplish above in autumn and often persisting into the spring.

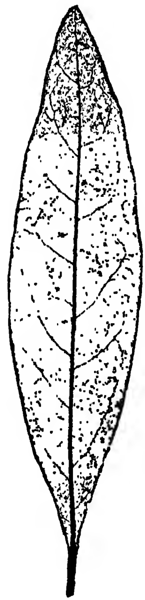

Fig. 60. Privet, *Ligustrum vulgare*, p. 201 (Ett).

‡‡ *Leaves oval, entire or faintly sinuate: quite deciduous, thin and herbaceous.*

Symphoricarpos racemosus, Mchx. Snowberry. Bush with long, thin, pale, wiry shoots. Leaves broad oval or nearly ovate, quite entire, acute, deep matt green above, glaucous or downy beneath, about 5 × 3·5 cm.; petiole short, 5 mm., grooved above. Leaves on the long shoots may be sinuate or wavy. Autumn leaves brown. Venation pinnate-reticulate.

B. Leaves alternate and spirally inserted on the long erect shoots, spiral or distichous on others.

(1) Leaves lobed, or cut into broad teeth too large to be regarded merely as serration or dentation. [For (2) see p. 231.]

(a) Lobing and venation pinnate. [For (b) see p. 216.]

[In certain cases the lowermost secondaries start from the base of the lamina, with the midrib, and diverge into the basal lobes: when these latter ribs and lobes are longer than those above, the leaf passes from pinnate towards palmate, and the intermediate stages may be termed pseudo-palmate. See p. 62.]

(i) Leaf oblong, evergreen, polished, hard, cut into large triangular spinose lobe-like teeth, often twisted out of the general plane, bordered by a tough marginal vein.

Ilex Aquifolium, L. Holly (Fig. 61). Small tree with crowded sub-verticillate branches and spinescent leaves, persisting more than a year. Petiole short, stipules obsolete (see p. 20). Lamina ovate, oblong or elliptic, acute or acuminate, 6—10 × 3—5 cm., stiff and leathery, tough and thick, the margins and even surface much waved; glabrous, deep shining green above, paler and duller beneath. Teeth strong and sharp, and, like the margins, strengthened by a cartilaginous rim, and not always attaining the size of lobes: on old stems the upper leaves may be entire or with a few small spinescent teeth at the apex. Dead leaves yellow, falling in summer. Forms with variegated leaves and with spines over the surface occur.

Venation pinnate-reticulate and looped. The secondaries leave the midrib in pinnate order, at first nearly straight, then curving outwards and tending to loop backwards, losing themselves in reticulations beneath the

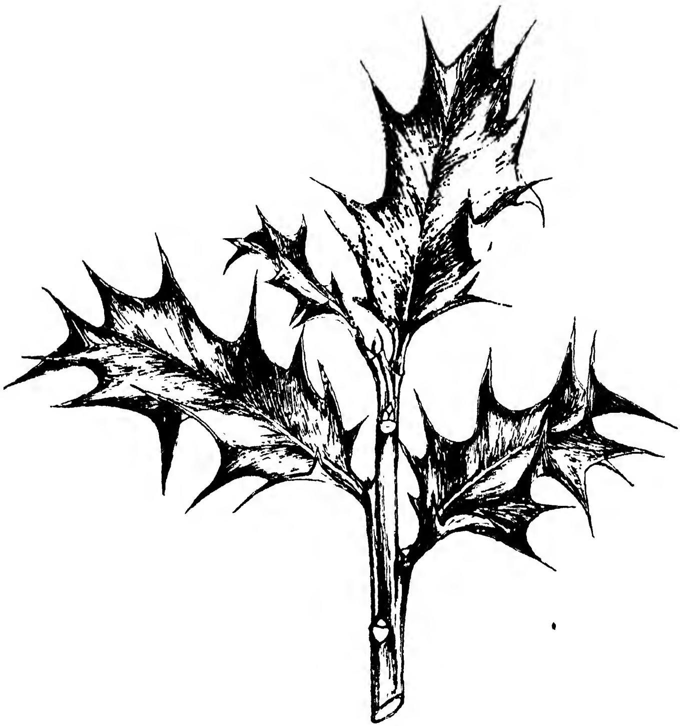

Fig. 61. Holly, *Ilex Aquifolium*, p. 203 (D).

margin, the branches of which unite into a strong marginal vein: a few run to the margin. Tertiaries leaving the inner sides of secondaries at acute angles, the outer at various open angles, and forming prominent large meshes.

(ii) Leaves neither spinescent nor evergreen.

(*a*) *Leaves exstipulate.*

Solanum Dulcamara, L. The Bittersweet has the majority of its leaves ovate-acute, cordate at the base, and entire; but they are often lobed at the base and hastate, or tripartite, or have an odd auricle. See p. 304.

(*β*) *Leaves stipulate.*

* Leaves broadly triangular ovate or pentagonal in form, and with pseudo-palmate venation, the lower secondaries longest.

† Leaves white-tomentose or hoary beneath, at least while young; base not tapering or decurrent. All the secondary veins passing to the lobes. Shoots not thorny.

⊙ *Lobes triangular, acute, sharply serrate, the lower longer and diverging. Older leaves losing the tomentum.*

Pyrus torminalis, Ehrh. Service Tree (Figs. 62 and 63). Medium-sized tree. Leaf broadly ovate-deltoid, ovate-rhomboid, or pentagonal oblong-ovate or cordate in general contour, large, 6—12 (8—10 × 4—8) cm., and cut in pinnate fashion into 5—7 or more large triangular teeth or lobes, the lower of which diverge, giving the leaf a pseudo-palmatifid appearance, an effect enhanced by the long lower secondary ribs, which come off from the base with the petiole. Lobes triangular acute or acuminate, sharply serrate or bi-serrate, unequal, the lower larger and the uppermost smaller and passing into teeth; separated by acute sinuses, the lower extending to near the middle. Base plane or slightly cordate. Lamina firm, green, shining and glabrescent or pubescent above, paler beneath and pubescent, bluish, or greyish and white-tomentose; especi-

ally so when young or on suckers. Petiole slender, 2—5 cm., or about half as long as the lamina. The loose downy tomentum is apt to disappear on old leaves. Autumn leaves yellowish brown.

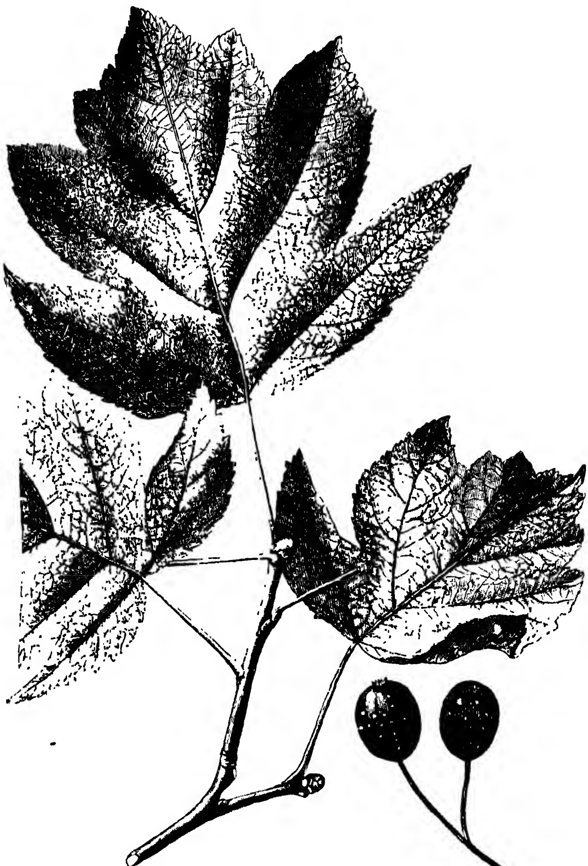

Fig. 62. Service Tree, *Pyrus torminalis*, p. 205 (Sc).

Venation pinnate, pseudo-palmate at the base, with about 6 (5—8) pairs of prominent and distant secondaries, of which the lower curve out; all ending in the pointed apex of the lobes, or the upper in teeth, without forking.

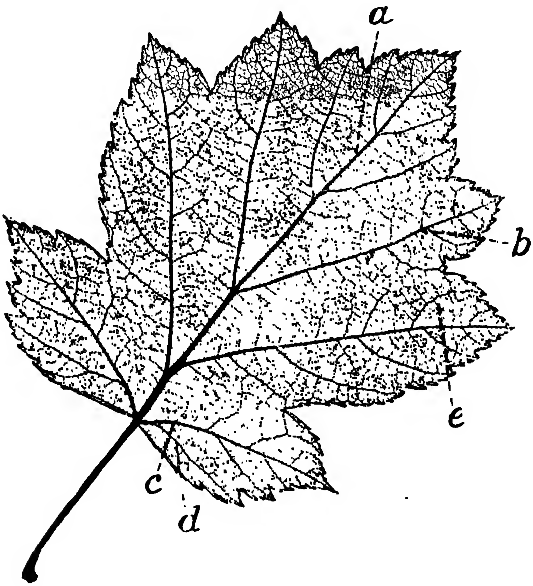

Fig. 63. Service Tree, *Pyrus torminalis*. Venation pinnate with pseudo-palmate base. *a* midrib; *b* secondary; *c* basal secondary coming off as if a primary in palmate venation; *d* outer branches of basal; *e* network formed by tertiaries and terminals, p. 205 (Ett).

Tertiaries mostly strong and pinnately diverging at acute angles on the middle and lower secondaries, somewhat distant, and very distinct on the basal pair; less so and tending to join as cross-ties above. Network very distinct though fine.

⊙ ⊙ *Lobes ovate or rounded-triangular, and irregularly sinuate-dentate; not sharply triangular and serrate.*

Populus alba, L. White Poplar, Abele (Figs. 64 and 65). Large tree with very variable foliage, the lower

Fig. 64. Abele or White Poplar, *Populus alba*, p. 208 (Sc).

surfaces of which are, like the shoots, petioles and buds, covered with white or grey tomentum. The leaves, thin

and pubescent above when young, vary in shape from sub-orbicular or broadly ovate to ovate-cordate, and more or less sinuate-toothed, to more or less deeply 3—5-lobed. As a rule, the leaves of suckers and at the ends of strong shoots are large, 6—12 cm. (or up to 17 or 18) long × 5—9 (or up to 15) cm. broad, and palmately 3—5-lobed, with rather broad sinuses and unequal broad blunt teeth; each

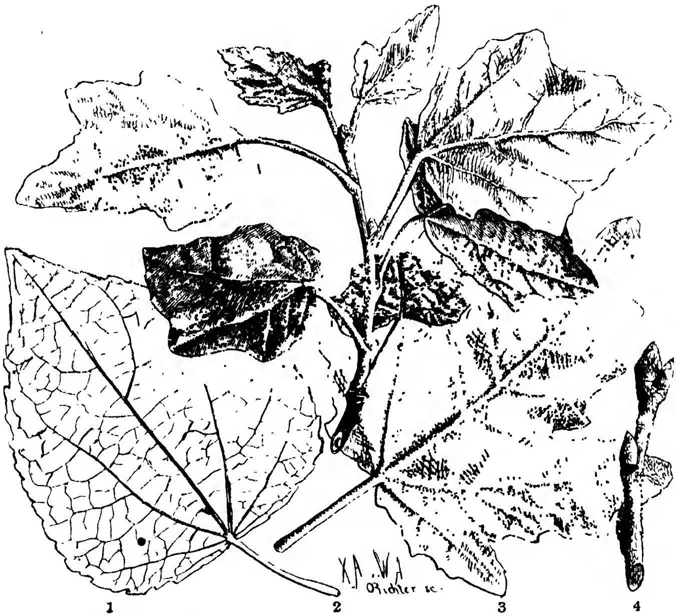

Fig. 65. White Poplar, showing the variations in form of the leaves (Wi).

lobe more or less ovate or triangular and sinuate-dentate. Those at the bases of shoots or on the weaker shoots and on old trees are smaller (4—7 × 3—4 cm. long), rounded, sub-orbicular or nearly heart-shaped, to ovate or oblong-ovate, with sinuate-angular lobes or blunt teeth (see p. 253).

Petioles of smaller leaves 2—3 cm. long, round and slender, those of larger leaves 5—9 cm. and compressed, white-tomentose. Lamina thick and tough, deep green and becoming glabrous above (the venation paler), densely white cottony or tomentose beneath; though there are varieties where this tomentum is greyer or even disappears. Upper stomata absent. Autumn leaves dark brown.

Venation as in *P. alba*, var. *canescens*, but more palmate, in accordance with the greater segmentation of the leaf.

[The leaves of *Pyrus Aria* are sometimes pinnately lobed, or even completely pinnate below (p. 175), and the more pubescent forms of *Quercus Robur*, var. *pubescens*, may be hoary white beneath (p. 215).]

†† Leaves not tomentose beneath, but glabrous or nearly so; cuneiform, with more or less tapering base. The alternate secondaries fork over the sinuses. Shoots thorny.

Cratægus Oxycantha, L. Hawthorn, Whitethorn (Fig. 66). Thorny shrub. Leaves variable, 3—7 × 2—6 cm.,

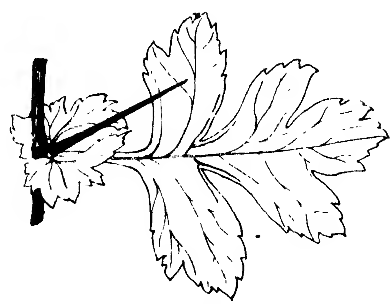

Fig. 66. Hawthorn, *Cratægus Oxycantha*, p. 210 (D).

broadly ovate or obovate, cuneiform, entire at the base, cut sometimes very deeply into 3—5, or even 7, pseudo-palmate

lobes, each acute and irregularly crenate-dentate, serrate or lobed; thin and tough, bright green, shining glabrous or glabrescent, or pubescent when young, especially on the margins and veins, bluish or yellowish green beneath. Stipules often large and leafy, half-ovate and serrate. Petioles 1—2 cm. up to as long as the midrib. Autumn leaves brown.

Venation pinnate or with pseudo-palmate base, the secondaries running direct and nearly straight to the margins, where they end in the teeth; or they fork, and the branches end similarly; but alternating with these there are other secondaries, or their branches, each of which goes direct to the sinus between two lobes, and may fork over it. The basal secondaries sometimes come off as if primaries and palmate.

[The var. *monogyna* is said to have the leaves bluish below and the secondaries more divergent.]

** Leaves oblong or obovate-oblong in outline; not tomentose beneath; pinnately and more or less sinuate-lobed, with distinctly pinnate venation, the lower secondaries shorter than those in midleaf.

† Lobes more or less rounded, slightly mucronate or acute, but not acuminate or drawn out to long points or teeth.

⊙ *Lobes rather angular, acute or mucronate, often separated by wide and rather deep sinuses, and themselves cut; leaf-base not auricled; stipules persistent on the leaf-bases and round the buds; surface rough with stellate or tufted hairs.*

Quercus Cerris, L. Turkey Oak (Fig. 67). Large tree, with persistent setaceous stipules surrounding the buds.

Leaves 5—7 × 2—4 (8—18 × 2—9) cm., narrow-oblong or oblong-obovate and broadest near the middle, attenuated

Fig. 67. Turkey Oak, *Quercus Cerris*, p. 211 (Sc).

or slightly cordate but not auricled at the base, obtuse; lobes rather narrow, rounded triangular, the middle incised nearly half-way, otherwise shallow, mucronate, rarely cut.

There is however much variation in the lobing, from large nearly serrate teeth to coarse sinuate, and occasionally nearly pinnatipartite segments; and leaves on suckers may be large and hairy. Deep dull green above, glabrous except for a few tufts of hairs; paler beneath and slightly velvety with stellate hairs, hardly hoary. Petiole short, 3—20 mm. Stipules long, setaceous, curved and tomentose, persistent on the leaf-bases.

Autumn leaves russet-brown to dull whitish grey. In young trees the dead leaves may remain on the twigs through the winter.

Venation reddish, pinnate as in *Q. Robur*; the secondaries about eight pairs.

⊙ ⊙ *Lobes obtuse, rounded; stipules not persistent round the buds; surface glabrous; base often auricled.*

Quercus Robur, L. Oak (Fig. 68). Large spreading tree with tufted shoots. Leaves oblong-obovate, 4—12 × 2·5—7 cm. (or up to 10—20 cm. long), widest about or just above the middle, often slightly asymmetrical, tapering, especially in young plants, or somewhat rounded or unequally auriculate at the base, cut to various depths in sinuate fashion. Lobes about 6—8, not quite regular, rounded oblong or somewhat triangular, obtuse or slightly emarginate or acute, or even slightly mucronate, entire or sinuate; sinuses rounded or acute. More or less coriaceous, glabrous, bright green, matt or scarcely shining above; paler, glaucous and glabrous or slightly pubescent beneath, or pubescent only in the axils of the venation, or in some varieties hoary. Young leaves pubescent. Petiole from 2—15 mm. up to 1—3 cm. long. Hairs simple or stellate. Tawny reddish when young, russet-brown in autumn. In young trees the dead leaves often hang on through the winter.

Venation pinnate. The midrib stout and prominent in its lower half, thinning out above, straight or slightly sinuous to the extreme apex. The midrib gives off strong secondaries at angles of 40—50°, which run nearly straight to the tips of the lobes and end there, the upper converging and the middle and lower ones diverging more or less. Average distance apart about $\frac{1}{6}$ the length of the midrib. Tertiaries leaving the outside of the secondaries at acute angles, and the inner side at about 90° and looping beneath the margins: the outer sometimes strong. Meshes well developed, the larger rectangular and rather loose.

Fig. 68. Oak, *Quercus Robur*, p. 213 (Ett).

[Of the several varieties described, three seem worthy of mention here. The var. *pedunculata* has the leaves typically quite glabrous, shortly petiolate or sub-sessile, auricled at the base, and the lobes rounded obtuse. The

var. *sessiliflora* has longer petioles, up to $\frac{1}{5}$ or more the length of the midrib (30 mm.); the lamina more or less pubescent beneath, at least in the axils of the veins, and tapering below without forming auricles, while the lobes tend to be more triangular and acute, and themselves sometimes slightly cut. The var. *pubescens*, again, is a form of the latter with more pronounced pubescence, or even grey tomentum on the buds, shoots and leaves, the latter being sometimes quite hoary beneath.]

†† Lobes sharply angular, long-acuminate and bristle-pointed, and irregularly sharply dentate; petioles rather long, slender.

⊙ *Lobes somewhat rectangular and ending in irregular prolonged teeth; sinuses deep and rounded.*

Quercus coccinea, Wangenh. Scarlet Oak. Large tree, with thin glabrous leaves, turning brilliant scarlet and crimson in autumn. Leaves about 12 × 10 (6—22 × 5—13) cm., bright green, or somewhat yellowish green beneath; thin and herbaceous, not coriaceous, glabrous both sides, broad oval, oblong, or more or less obovate, deeply pinnatifid; lobes slender, spreading, and somewhat toothed. each apex ending in a prolonged subulate filament. Young leaves with tomentum in the angles of the veins. Petiole about 3—6 cm. long.

Venation very like *Q. sessiliflora*, but the strong secondaries are sinuous; some run direct to the margin, others form loops, alternately, and they may be slightly more distant. Network loose, with large meshes.

⊙⊙ *Lobes triangular, and irregularly toothed; sinuses less deep and more angular.*

Quercus rubra, L. Red Oak. Like *Q. coccinea*, the leaves reddish in spring and turning orange to scarlet or brownish and duller red in autumn, but less deeply cut into more triangular acuminate lobes, with more angular

sinuses. Leaf about 8—11 × 5—6 (8—25 × 6—16) cm., ovate or elliptic, coarsely sinuate-dentate or with broad and shallow sinuses cutting it into acuminate and coarsely-toothed lobes; tapering or rounded, and entire below, glabrous and shining green both sides, or bearded in the axils of the veins. Petiole $\frac{1}{4}$ to $\frac{1}{2}$ as long as the leaf.

[There are various so-called cut-leafed forms of Oak, Beech, Lime, &c. which would come here if we were concerned with the vagaries of cultivated trees.]

(b) Lobing and venation palmate.

[For (ii) see p. 222.]

(i) Leaves exstipulate.

(*a*) *Leaves dark green, shining, coriaceous and evergreen. Shoots climbing by means of adventitious roots.*

Hedera Helix, L. Ivy (Figs. 69—71). Root climber with distant, distichous or spiral, large leaves, or creeping and with smaller leaves, containing resin-canals and peculiarly aromatic when bruised. Leaves thick, 3—8 × 2—6 cm. (up to 3—10 cm.), broadly pentagonal and 3—5-lobed on the climbing and creeping shoots; but entire and ovate, rhomboid-ovate, or more or less deltoid or nearly lanceolate and acuminate on the free flowering shoots. Lobes triangular, hardly acute, entire or slightly sinuate; sinus wide, deep or shallow; base cordate or rounded. Upper surface polished deep green, often with paler venation, or parti-coloured patches; paler beneath. Petiole 1—4 cm. Dying leaves brown.

Venation palmate or pseudo-palmate and reticulate, or pinnate with pseudo-palmate base. Three or five strong primaries radiate from the petiole, and give off secondaries which rapidly break up into a distinct wide-meshed network. Tertiaries strong and prominent. There is a tendency to loop beneath the margin. The two outer primaries in the lobed and angular larger leaves reflexed.

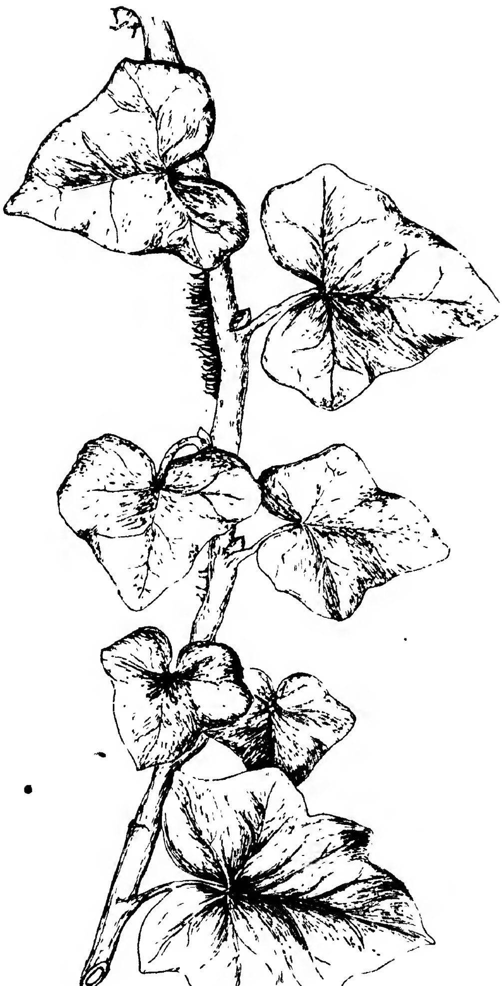

Fig. 69. Ivy, *Hedera Helix*, a climbing shoot, p. 216 (D).

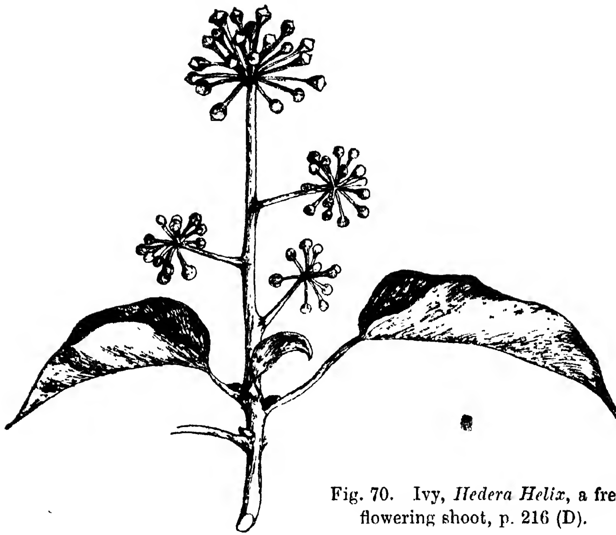

Fig. 70. Ivy, *Hedera Helix*, a free flowering shoot, p. 216 (D).

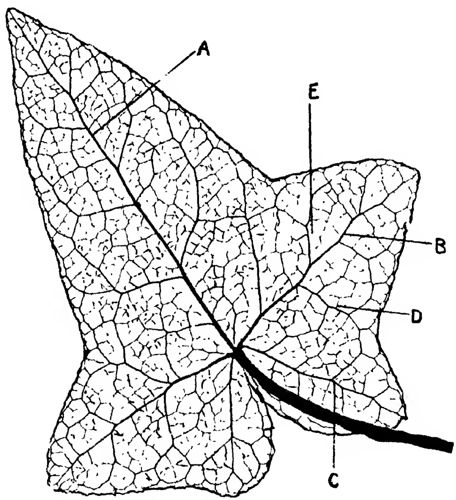

Fig. 71. Ivy, *Hedera Helix*. Venation pseudo-palmate or palmate. *A* midrib; *B* secondary; *C* basal secondary; *D* tertiary; *E* network of terminals, &c., p. 216 (Ett).

Many varieties are known in culture, some with variegated foliage.

(β) *Leaves not dark, shining, coriaceous or evergreen: shoots not climbing.*

* Pulvinus armed with single or triple spines. Leaves not more than 3—6 cm. in diameter.

Ribes grossularia, L. Gooseberry (Fig. 72). Spinescent bush. Leaves in tufts on the dwarf shoots, small, about 2—3·5 (3—6) cm. in diameter, on distinct petioles; suborbicular or ovate to rounded pentagonal cut about halfway in into 3—5 rounded lobes, which are again irregularly

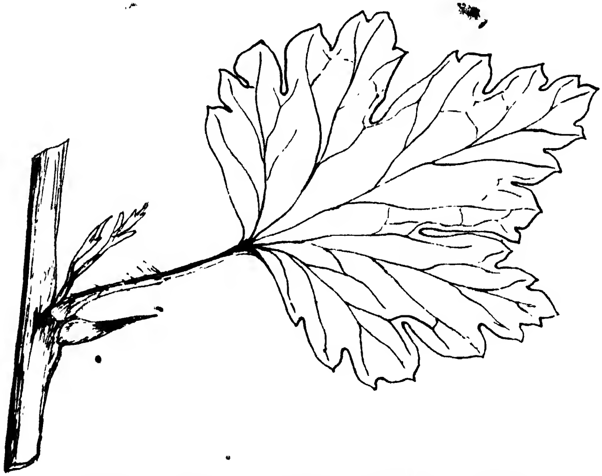

Fig. 72. Gooseberry, *Ribes Grossularia*, p. 219 (D).

lobed and crenate. Velvety-pubescent, especially on the margin and veins, or rarely glabrous above: paler beneath. Sinus narrow, shoots sometimes with scattered spines. Petiole 1—2 cm. Autumn leaves yellow and brown.

Venation palmate, the primaries and secondaries all

ending in the tips of the lobes and lobules, thinning out much as they approach the margin, as also do the secondaries ending in the lobules or teeth. Secondaries few, the lateral ones almost devoid of outer nerves. Tertiaries and network incomplete.

** Shoots and pulvini devoid of spines. Leaves up to 6—12 cm. broad.

† Leaves strongly aromatic when bruised, owing to yellow glandular hairs beneath.

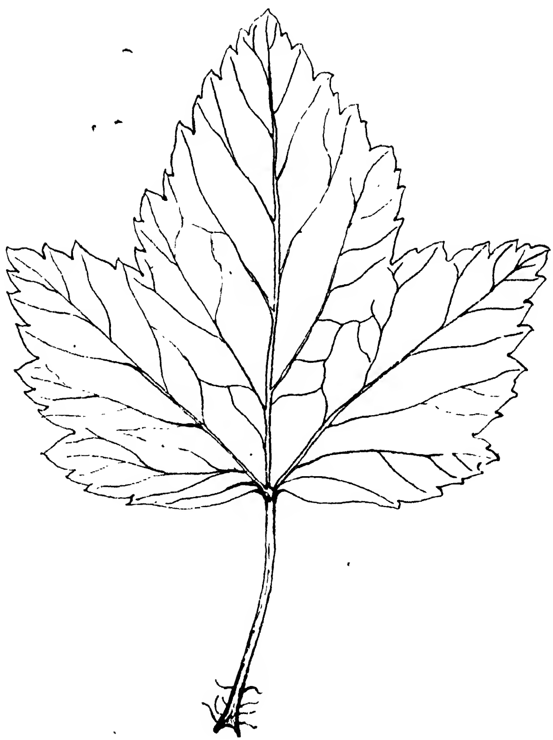

Fig. 73. Black Currant, *Ribes nigrum*, p. 221 (D).

Ribes nigrum, L. Black Currant (Fig. 73). Bush. Leaves more or less pentagonal heart-shaped, coarse, angular, about 4—7 × 5·5—11 cm., cut into 3—7 triangular, acutely serrate or bi-serrate lobes, dark green, glabrous and shining, or slightly pubescent, coarse and rough above; paler and glandular hairy beneath, especially when young. Sinus deeper and leaves larger than in *R. rubrum.* Base cordate. Petioles slender, 3—4 cm., pubescent. Glandular hairs golden yellow. Autumn leaves yellow and brown.

Venation as in *R. rubrum.*

†† Leaves devoid of glands and strong odour.

Ribes rubrum, L. Red Currant (Figs. 74 and 75).

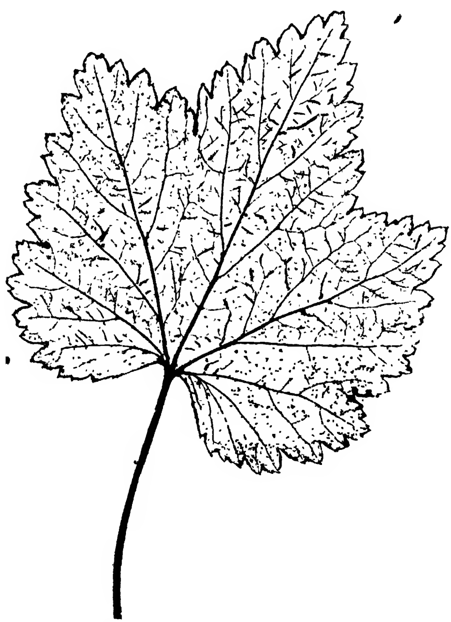

Fig. 74. Red Currant, *Ribes rubrum*, p. 221 (Ett).

Leaf about 4·5—8 × 5—9 cm., rounded in contour, somewhat cordate at the base, palmately 3—5-lobed; lobes usually obtuse, unequally and coarsely serrate, smooth above, young leaves softly hairy but eglandular, and paler

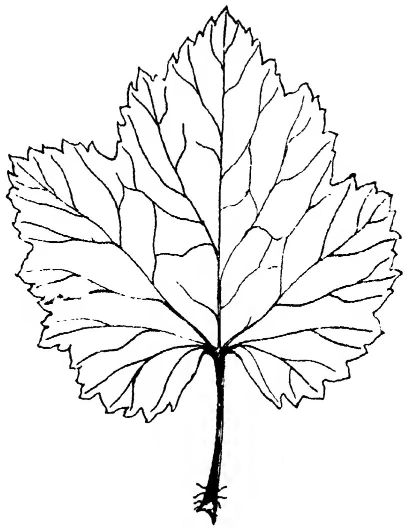

Fig. 75. Red Currant, *Ribes rubrum*, p. 221 (D).

beneath, later with scattered hairs. Petiole rather long, 3—7 cm., glandular-pubescent, with membranous margins. Young leaves pubescent, especially beneath. Autumn leaves yellow and brown.

Venation palmate, and much stronger than in *R. Grossularia*. Meshwork loose and tertiaries tending to form cross-ties.

(ii) Leaves stipulate.

(*a*) *Leaves tomentose or hoary-white below, at least while young.*

* Lobes triangular-ovate, deeply incised, irregularly sinuate-dentate, or bluntly toothed.

Populus alba. The leaves on suckers and strong shoots are often large and 3—5 palmatifid. Thick and tough, smooth above, white-tomentose beneath; the lobes unequally sinuate, cut and toothed, and up to 15 cm. or more in diameter (see p. 208).

** Lobes acutely triangular, and sharply serrate; venation pseudo-palmate.

Pyrus torminalis. The leaves are really pinnately lobed and veined, but sometimes the lowest lobes and secondaries are so strong and divergent as to be pseudo-palmate, and the student may seek for them here (see p. 205).

(β) *Leaves not tomentose or hoary below.*

* Leaves containing white latex.

† Leaves thick, with large pulvini and leaf-scars.

Ficus Carica, L. Fig (Fig. 76). Shrubby tree, with very variable leaves, and milky juice. The leaves (8—16 × 6—18 cm.) may be nearly entire, with pinnate venation; but are more commonly palmately 3—7-lobed, or even 5-partite, and veined, cordate at the base, each lobe more or less rectangular or rounded, long, with dilated ends, obtuse or acute, sinuate or again cut, and separated by shallow or very deep wide sinuses. Lamina thick, dark green and scabrous above, and pubescent or nearly tomentose and paler beneath. Base cordate. Petiole stout, 2—5 cm. long. Young leaf convolute.

The lowest leaves nearly entire, rounded ovate, with more or less tapering base. Autumn leaves yellow.

Venation palmate, the lateral basal veins—at least the inner ones—very strong, far more so than the pinnate

Fig. 76. The Fig, *Ficus Carica*, p. 223 (Wo).

secondaries from the midrib, and ending in the points of the lobes. Lowest basal primaries short and feebler, and forming angles of 90° or more with the midrib. Secondaries curving forward and looping into an infra-marginal vein. Tertiaries forming a prominent network.

†† Leaves thin; pulvinus and leaf-scar small.

Morus alba, L. Mulberry (Figs. 77 and 78). Small tree. Leaves about 3—10 cm. in diameter; variable, ovate or broadly ovate, to rhomboid; or more or less cordate or oblique at the base, acute and coarsely and unequally serrate, and cut into 2—5 lobes, with rounded entire sinuses; the lobes broadly ovate or rounded, unequal, usually 3—5 and the middle larger, or the leaves may be 5-partite. Herbaceous green, thin, glabrous, and

shining, or pubescent on the veins and in their axils below. Petiole pubescent, channelled above; stipules lanceolate and caducous, 1—3 cm. long. Lobes coarsely toothed or serrate. Young leaves not tomentose beneath. Dying leaves yellow.

Fig. 77. Mulberry, *Morus alba*, p. 224 (Wo).

Venation pseudo-palmate as in *Populus alba*, but the tertiaries run irregularly into an open network. Secondaries straight, or nearly so, not sinuate. Reticulation very loose and not prominent.

In *Morus nigra*, the Black Mulberry, the leaves also

vary much in size (9—15 × 7—15 cm.) and shape, but are larger and rougher than in *M. alba*; petiole about 1—2 cm. long, usually more cordate at the base, ovate-acute or heart-shaped (resembling the Lime), or rarely cut to the middle into 3—5 lobes, which are often again cut, or

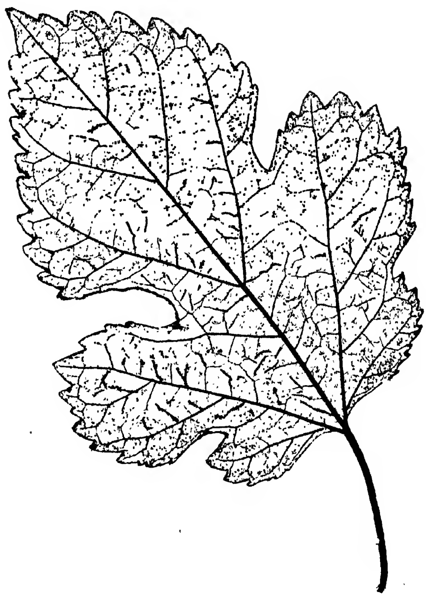

Fig. 78. Mulberry, *Morus alba*, p. 224 (Ett).

obtuse and coarsely and unequally serrate. Upper surface harsh, scabrous pubescent; lower with short soft hairs, or both surfaces velvety. Stipulate. Petiole milky, pubescent, about $\frac{1}{4}$ the length of the midrib, hardly grooved. Young leaves hairy beneath. Venation as in *M. alba*.

** Leaves devoid of latex, and glabrous or nearly so.

† Leaves small, about 3—6 cm. in diameter, cuneate; lobes crenate, irregular. Shoots thorny.

Cratægus Oxycantha. In the case of deeply-lobed leaves the venation is pseudo-palmate, and the leaf appears palmate, owing to the divergence of the long basal secondaries from the point of attachment of the petiole into the larger lobes (see p. 210).

†† Leaves large, up to 10—20 cm. in diameter, broad pentagonal or rounded, 3—5-lobed; shoots not spiny or thorny.

⊙ *Many leaves with opposed tendrils; petiole solid at the base and the buds exposed; not bearing stellate hairs, but containing needle-like raphides. Stipules scaly and caducous.*

Vitis vinifera, L. Vine (Figs. 79 and 80). Tendril climber, the tendrils all leaf-opposed. Leaves rounded heart-shaped, about 6—14 cm. in diameter, palmatifid into 5 or rarely 3 lobes, the incisions half-way in or more, and narrow; cordate at base, and of a pleasant green colour. Lobes ovate, acute, sinuate and irregularly cut, and coarsely serrate; glabrous, or more or less pubescent or velvety below. Petiole up to 8 cm., hardly as long as the leaf, nearly cylindrical, striate, dilated below, thick and herbaceous; stipules scaly and caducous. Autumn leaves brilliantly coloured, orange, red, &c. Young leaves covered with deciduous tomentum and pearly drop-like glands.

Venation palmate, with 3—5 basal ribs, usually of 5 primaries, the outer reflexed, all ending in the points of the lobes, and giving off pinnate secondaries which run to the larger teeth or lobules. Secondaries numerous, those

from the outside of the lateral primaries especially prominent. Tertiaries also numerous and well developed, forming cross-ties and prominent but loose meshes.

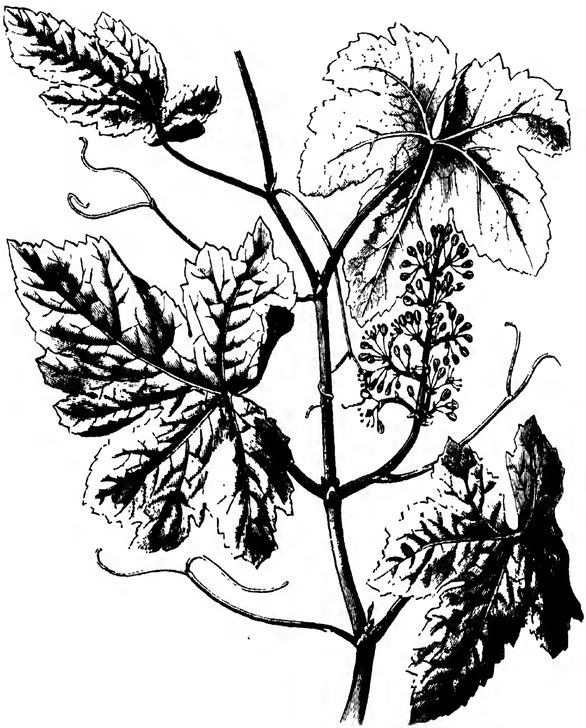

Fig. 79. Vine, *Vitis vinifera*, p. 227 (Sc).

⊙ ⊙ *No tendrils. Petiole dilated below and hollowed into a cup in which the bud is buried; covered with stellate hairs, especially when young. No raphides. Stipules foliaceous and embracing.*

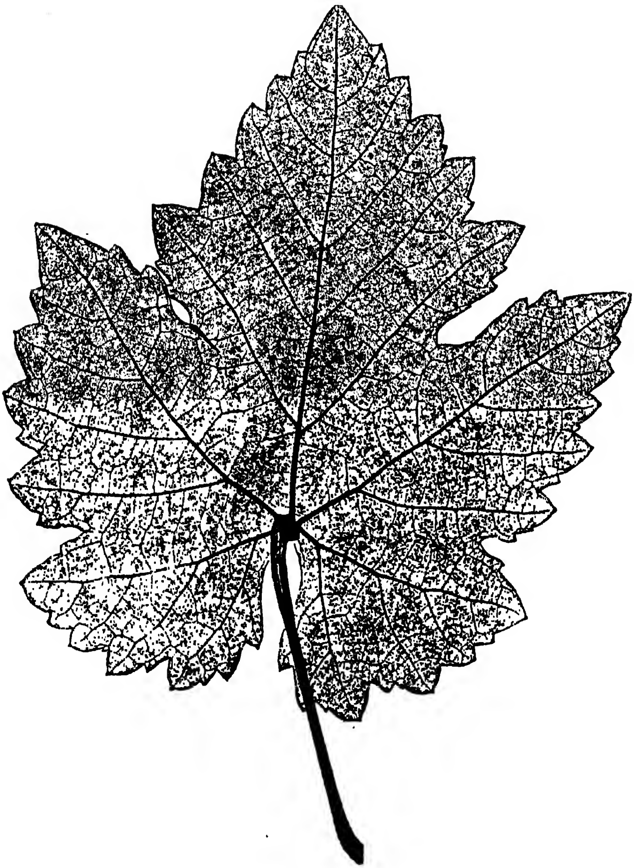

Fig. 80. Vine, *Vitis vinifera*, p. 227 (Ett).

☐ *Lobes narrow, triangular acuminate, divided by deep and rather narrow sinuses; young leaves tomentose, then glabrous.*

Platanus orientalis, L. Plane (Fig. 81). Large spreading tree. Leaves plane or cordate at the base, deeply cut into 3—5 lobes, each triangular or long and nearly lanceolate, and somewhat cut and dentate in the same way; the incisions extending about half-way in. Glabrous, but densely covered with stellate hairs when young, especially on the venation beneath. Petiole green, shorter than the limb. Stipules connate into a leafy ring round the shoot and often hanging on it. Autumn leaves leather yellow to orange-brown.

Fig. 81. Plane, *Platanus orientalis*, p. 230 (Ett).

Venation pseudo-palmate, with 3—5 primaries, of which the midrib is the strongest, the basals, when present, being weakest: all running to the tips of the lobes. Mid-

rib thinning out above, sinuous. Basals originating from near the base of the laterals, of which they are branches, and diverging at acute angles, running horizontally or slightly backwards: they, like the laterals, giving off conspicuous outer branches, most of which run to the tips of the lobes or large teeth. Secondaries sinuate, running to the margin, the lower at angles of 40—50°, the upper at 55—60°. Tertiaries well developed and often as cross-ties. Network very complete, the veins up to the fifth order being distinguishable.

□□ *Lobes broadly triangular, separated by shallow wide sinuses extending only about ⅓ of the way in; almost tomentose below.*

Platanus occidentalis, L. Western Plane. Similar to the last, but leaves 9—16 × 9—20 cm. in diameter, usually truncate at the base; lobes broader, and incisions shallower and broader, and tomentum more persistent. Venation as in *P. orientalis*. Petiole often red-brown, 3—10 cm. long. Stipules brown and woolly, caducous. Leaves leather yellow to red-brown in autumn.

For distinctions between the Planes and Maples see p. 186.

(2) Leaves not cut into lobes, but at most coarsely toothed, or sinuate.

(a) Leaves distinctly serrate, dentate or crenate. [For (b) see p. 284.]

(i) Leaves stipulate. [For (ii) see p. 281.]

[If the minute hair-like prolongations of the sheath of the Barberry leaf are stipules, this species comes here. The bush has spinose ciliate leaves. See p. 162. See also note on p. 161.]

(*a*) *Leaves distichous on the long lateral shoots.*

* Leaves more or less lanceolate.

† Leaves coriaceous, polished above, evergreen, glandular serrate; venation pinnate, reticulate and looped, obscure.

⊙ *Shoots and petioles green, leaves somewhat oblanceolate; secondaries slightly prominent beneath, with circular glands at the base beneath on each side of the midrib.*

Prunus Laurocerasus, L. Cherry Laurel. Shrub, with leaves smelling of bitter almonds when crushed. Leaf 10—15 × 3—4 cm., broadly lanceolate or slightly obovate-lanceolate, and bluntly acuminate, persistent, tough, glabrous, dark bright green and polished above, paler matt green below. Margin somewhat reflexed, with distant small serrature. Petiole stout and short, about 5 mm. long. Midrib prominent below, giving off about 8—10 much finer secondaries on each side, in pinnate order: these curve forward, become very indistinctly looped, and fade away into the obscure reticulation. There are one or two depressed circular glands near the base on each side of the midrib, often purplish in summer, and very obscure in winter. Stipules very evident on young leaves, deciduous, their scars usually discernible. Dying leaves yellow and brown.

⊙ ⊙ *Shoots and petioles reddish to purple, leaves more ovate-lanceolate and smaller and more crowded; also thinner, harder, and darker, the venation less prominent; no glands.*

Prunus Lusitanica, L. Portugal Laurel. This closely-allied species has purple shoots and no glands on the leaves, and the latter are thinner and harder. The leaves are also smaller, darker above, more crowded (the internodes shorter) and pendent, and have closer, more

serrated teeth, and no smell of almonds. Venation as in the last, but the secondaries not protruding.

†† Leaves thin, not evergreen and polished; cuspidate-dentate. Venation strictly pinnate.

Castanea vesca, Gaertn. Chestnut (Fig. 82). Large spreading tree. Leaves lanceolate, or oblong- to ovate-lanceolate, about 15—20 × 5—7 (8—25 × 4—8) cm.,

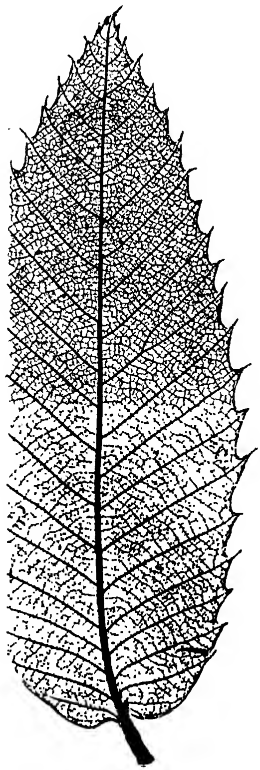

Fig. 82. Chestnut, *Castanea vesca*, p. 233 (Ett).

acuminate, regularly dentate, with sharply-prolonged forward-curved teeth, into each of which one of the pinnate veins passes. Thin, firm, glabrous, bright matt green or somewhat shining, paler beneath; young leaves pubescent beneath with small stellate hairs. Petiole short (5—25 mm.). Stipules about 15 mm. long. Leaves plicate in bud. Autumn leaves yellow.

Venation strongly strict-pinnate; midrib tailing off into the apex, straight; secondaries nearly straight to the margins, each ending in a tooth: the lower slightly divergent, the upper converging or not. Tertiaries connecting, but not looped, beneath the dentate-serrate margins; rather prominent, simple and branched. The lowest secondary coming off at about 90°; the middle and upper secondaries at acute angles with the midrib. Each pair of secondaries separated by a distance equal to $\frac{1}{15}$ or less of the length of the midrib, and often closer. Secondaries simple, rarely forked, at angles of about 50—65°; the lowest more open, the upper less so. Lowest secondaries much shorter than those in the middle of the leaf, and devoid of prominent outer nerves. Ultimate meshwork very fine.

** Leaves not lanceolate; but broader, ovate or obovate to cordate, oblique; sharply serrate or bi-serrate.

† Leaves heart-shaped, oblique; venation pseudo-palmate at the base.

Tilia europæa, L. Lime (Fig. 83). Large tree. Leaves typically cordate oblique, 5—10 cm. long, on long petioles; or ovate-cordate to sub-orbicular acuminate. Acutely serrate, except at the entire basal region, dark green and glabrous above; paler, bluish glaucous, or pubescent, or

velvety beneath, with reddish or whitish hairs in the axils of the veins. Tough when old. Petiole 2—4 cm., cylindric,

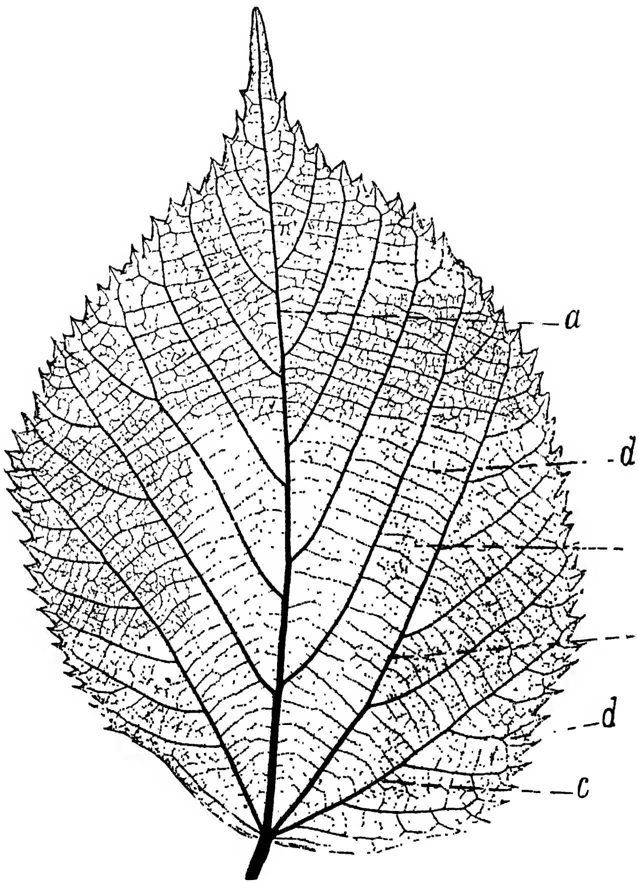

Fig. 83. Lime, *Tilia europæa*. Venation pinnate with pseudo-palmate base. *a* midrib; *b* secondary; *c* basal secondary, coming off as in palmate venation; *d* tertiaries; *e* network of quaternaries and terminals, p. 234 (Ett).

and, like the shoots, pubescent in youth, becoming glabrous. Autumn leaves yellow or yellowish brown.

Venation pinnate, pseudo-palmate at the base; the basal principal veins on each side of the midrib strong, diverging at the junction with the petiole and running nearly straight to the margin, emitting outer lateral branches as they go. At the margin they break up and send tertiaries into the teeth: the secondaries end similarly, and are numerous. The lateral basals send strong branches from their outer sides, which end similarly. Tertiaries strong and numerous, forming distinct cross-ties and a very evident reticulation of close meshes. Tufts of hairs in the axils of the veins below.

Several varieties are described, of which the most important are *T. grandifolia*, with larger leaves (4—10 × 4—9 cm.), velvety beneath and with the hairs in the angles of the veins whitish; teeth unequal, sharply pointed; and *T. parvifolia*, with small leaves (4—7 × 2—7 cm.) and relatively longer petioles (2—3 cm.); glabrous except for the tufts of reddish-yellow hairs in the angles of the veins beneath.

†† Leaves not typically heart-shaped, more ovate or obovate, and bi-serrate; venation strictly pinnate all the way up.

⊙ *Shoots, petioles, and midrib with reddish, capitate glandular hairs; young leaves conduplicate. Stipules persistent.*

Corylus Avellana, L. Hazel (Fig. 84). Shrub with glandular shoots, and persistent stipules. Leaves broadly oval to obovate or sub-orbicular, 6—12 cm. or more long and two-thirds as broad (7—13 × 6—10), slightly cordate and oblique at the base, suddenly acuminate or cuspidate, and occasionally (on suckers) feebly trilobate at the apex;

sharply bi-serrate. Green, softly pubescent when young, then coarse and glabrous or glabrescent, with a few hairs in the angles of the veins beneath. Young shoots, stipules and petioles covered with reddish, perpendicular, capitate

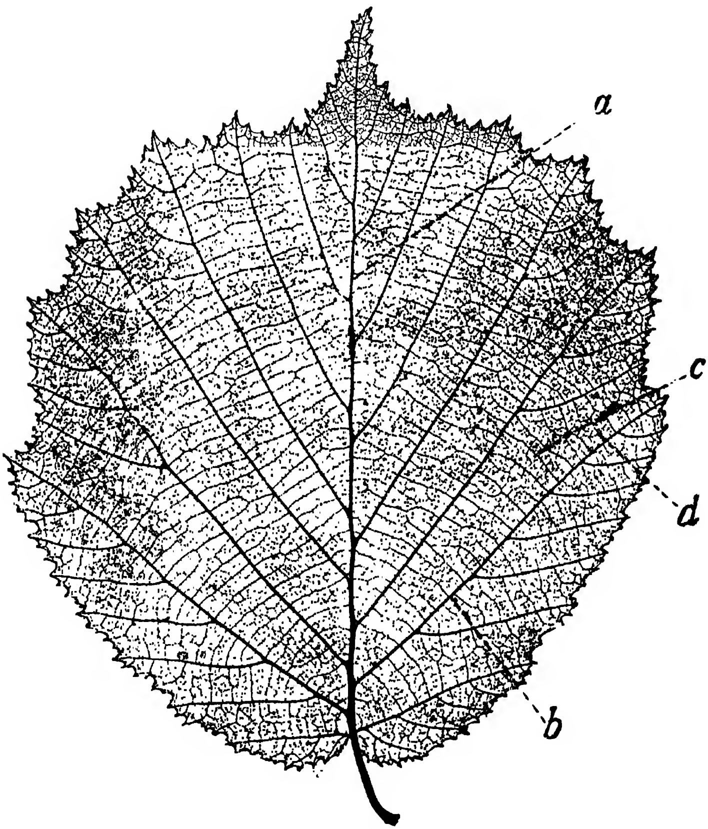

Fig. 84. Hazel, *Corylus Avellana.* *a* midrib; *b* secondary; *c* tertiary; *d* quaternaries and terminals, p. 236 (Ett).

glandular hairs, and such are generally present also on the midrib and veins. Plaited in bud. Petiole short, 0·5—1, rarely up to 3 cm.; stipules oblong-obtuse. Autumn leaves yellow.

The glandular petioles at once distinguish *Corylus* from the Elms or Hornbeam; but the glands are sometimes very feebly developed, and recourse must be had to the bark, flowers and fruit.

Venation strict-pinnate, the secondaries, about half-a-dozen on each side, straight to the margins where each ends in the point of a lobe. Tertiaries not looped beneath the bi-serrate margin. Secondary nerves distant about $\frac{1}{8}$ the length of the midrib; the lowest far shorter than those in the middle of the leaf, and sending out at least 4—5 outer tertiaries which are conspicuously stronger than the normal tertiaries elsewhere, and emerge at more acute angles. Leaf-base nearly equal and somewhat cordate.

(·) ⊙ *No glandular hairs. Stipules caducous.*

▱ *Young leaves plicate but not conduplicate.*

Carpinus Betulus, L. Hornbeam (Fig. 85). Large tree with Elm-like leaves, and Beech-like trunk and buds. Leaves 4—10 × 3—5 cm. (4—11 × 2·5—6 cm.), ovate-elliptic or ovate-oblong, to broad ovate-lanceolate, acute or acuminate, slightly oblique and cordate or rounded at the base, and sharply bi-serrate or sinuate-serrate, with thick teeth. Bright matt green and glabrous above, paler and sometimes slightly pubescent on the venation or in the angles beneath. Slightly gimped between the salient teeth in which the secondaries end, so that the margin appears faintly cut into bays. Petiole short (10—15 mm.), eglandular. Lamina plaited parallel to the veins in bud

(i.e. plicate, but not conduplicate), pubescent. Autumn leaves yellow.

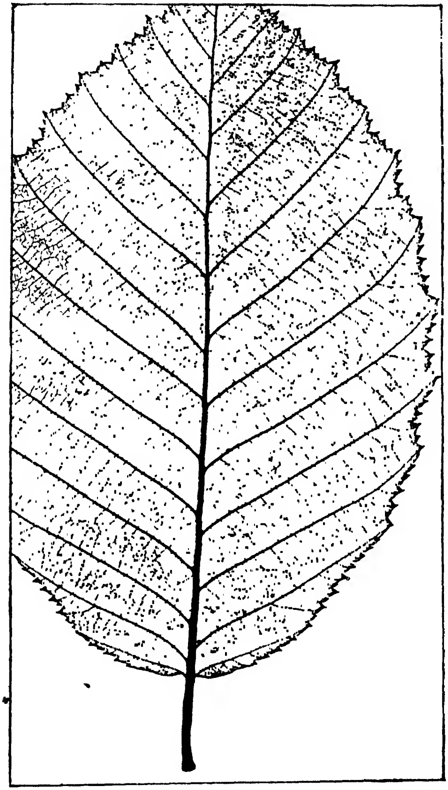

Fig. 85. Hornbeam, *Carpinus Betulus*, p. 238 (Ett).

The Elms have more forked secondaries, are usually harsher, and have much smaller buds and stipules, and the oblique leaf is conduplicate and less plicate in bud. The most obvious distinctions are derived from the bark, flowers, and fruits.

Venation strict-pinnate, midrib strong to the middle giving off on each side 10—15 sharp secondaries, straight —or the lowermost somewhat divergent—to the bi-serrate margin, each ending in a tooth, and alternate or the lowest opposite. Tertiaries not looped, very fine and much anastomosed: the outer at acute, the inner at 90° or more obtuse angles: those from the midrib at about 90° or more. Each pair of secondaries distant about $\frac{1}{12}$ of the length of the midrib, the lowest much shorter than those in the middle of the leaf, and almost devoid of conspicuous outer nerves, but with a few weak ones. Leaf-base equal and not cordate. Angle between secondaries to primaries 35—45°. Secondary segments narrow, the middle nearly linear. Tertiaries connecting. Network well developed, meshes rather loose and rounded.

□□ *Young leaves conduplicate.*

§ *Leaves more or less ovate, not more than 6—10 cm. long, at most pubescent beneath, apex acute or slightly acuminate; petiole relatively long.*

Ulmus campestris, Sm. Elm. Tall tree, twigs often with corky ridges. Leaves about 6—10 cm. long (2—10 × 2—5), lanceolate to broad cordate, ovate, or elliptic, acute or acuminate, usually very oblique at the base. Obtusely bi-serrate, the main teeth curved forwards; coarse, nearly smooth above, firm, with tufts of hairs in the angles of the veins below, not glandular. Petiole short, 4—10 mm. and smooth or nearly so. Stipules caducous. The leaves are very firm, almost coriaceous. Autumn leaves golden yellow.

Venation pinnate, the secondaries straight to the bi-serrate margin and ending in the teeth. Tertiaries not looped beneath the margin. Secondaries about 10—12

(9—14) pairs, distant about $\frac{1}{12}$—$\frac{1}{10}$ the length of the midrib, the lowermost shorter than those in the middle of the leaf, and almost devoid of conspicuous outer nerves. Leaf-base oblique-cordate: teeth rather blunt. Both surfaces more or less rough, with short stiff hairs; or glabrous.

§§ *Leaves more or less obovate, up to 12—18 cm. long, velvety beneath, apex long acuminate, petiole relatively very short.*

Ulmus montana, Sm. Wych Elm (Fig. 86). Large tree, usually more spreading and with stouter and more hairy twigs than *U. campestris*. The leaves larger, 12—18 cm. long, and broader, up to 8—10 cm. (8—16 × 4—10), and often obovate or even angular and slightly lobed above; and cuspidate, or doubly and even trebly acutely serrate, upper teeth often incurved; rougher above and more velvety beneath, hiding the hairs in the angles of the veins. Nearly sessile: petiole 3—8 mm. Autumn leaves golden yellow.

Venation resembling that of *U. campestris* (type of *Carpinus Betulus*), but the leaf usually rougher above and more hairy, almost velvety below. Shoots also stouter. Midrib straight, thinning out above, strong below. Secondaries usually slightly curved forwards and forked, or with a few prominent outer veins, rarely quite simple. Angle 50—65 degrees: average distance apart $\frac{1}{12}$—$\frac{1}{10}$ the length of the midrib. Tertiaries at slightly acute angles, connecting, sinuous. Meshes rather loose and not prominent.

[There is still a good deal of confusion regarding the Elms, of which the following three, described as species by Continental botanists, may be particularised.

U. glabra, Mill. Twigs thin, glabrous, shining. Leaves

very firm and smooth, with hairs in the angles of the veins, base oblique, coarsely blunt-serrate, 2—10 × 1·5—

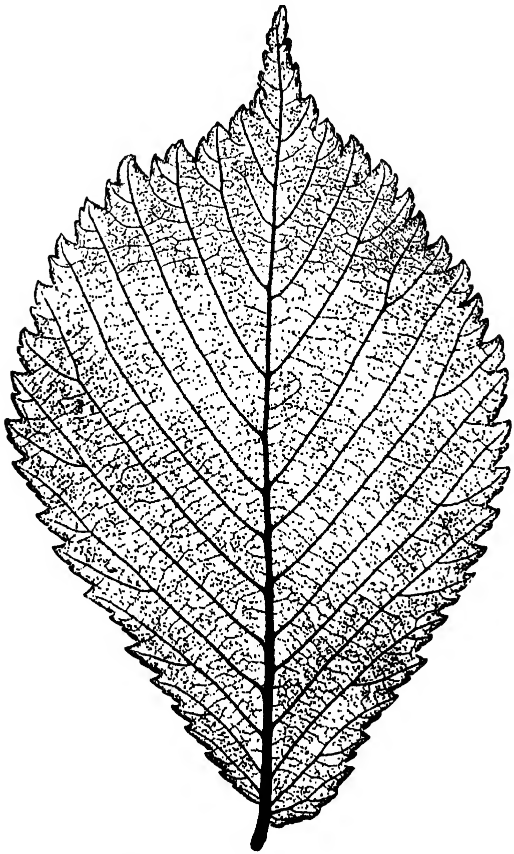

Fig. 86. Wych Elm, *Ulmus montana*, p. 241 (Ett).

5 cm. Petiole 4—10 mm. long, smooth or slightly pubescent. The larger leaves on suckers are however hairy. This is a variety of *U. campestris*, Sm.

U. campestris, L. Twigs thick, bristly. Leaves thin, venation hairy, upper surface scabrid, base hardly oblique, margins sharply bi-serrate. Leaves much larger, 8—16 × 4—10 cm., especially the terminals, which are often cut into 3 tips. Petiole very short and thick, 3—8 mm., hairy. This is the species *U. montana*, Sm.

U. effusa, Willd. Thin glabrous shining twigs. Leaves thin, glabrous or roughish above, hairy beneath, very oblique, sharply bi-serrate. Petiole short, 3—9 mm., pubescent. This is not British, and is the same as *U. pedunculata*, Foug.

Numerous other forms have been distinguished, of which only one need be mentioned, var. *suberosa*, Ehrb., a variety of *U. campestris* with very corky twigs.

The leaves of the Beech, usually entire, are occasionally sufficiently sinuate-dentate to be looked for in this group. They are oval, glabrous and glossy, and strict-pinnate. See p. 284.]

(β) *Leaves spiral on both long and dwarf shoots.*

* Leaves lanceolate, usually at least 4 times as long as broad, and often much longer.

† Leaves silky-pubescent, at least beneath.

⊙ *Leaves small, at most 1—6 cm. long, with obscurely serratulate margins, and stipules minute, or obsolete. Small creeper.*

Salix repens, L. Creeping Willow. Small creeping arenicolous bush, with silky-velvety shoots and buds. Leaves very variable, about 25—40 × 5—8 mm. (1—6 cm. × 1·5—15 mm.), elliptic to broad oval or ovate, oblong-lanceolate to linear-lanceolate or even sub-linear. Silvery-silky both sides, or glabrous and dark green above and

silky or hoary tomentose beneath, the appressed hairs directed forwards. Margins recurved, entire or serratulate, with small distant glandular teeth. Petiole very short, and the stipules minute or obsolete, and seldom seen, but elliptic or linear-lanceolate. The lower leaves may be at length glabrous, and merely glaucous beneath. The apex obtuse or acute, or suddenly acuminate and then generally oblique and spout-like. No stomata on the upper surface. Autumn leaves yellow and brown.

Venation pinnate-reticulate, the secondaries leaving the midrib at acute angles, prominent beneath, and rapidly breaking up into a close network of tertiaries, all fine, and the ultimate venation therefore obscure. About 5—6 secondaries on each side, fairly equidistant.

Several varieties and hybrids are described, differing in the combination of characters referred to above.

⊙ ⊙ *Leaves longer*, 6—20 × 0·5—2 *cm. or more, serratulate or serrate, stipules caducous. Trees or osiers.*

▱ *Leaves linear-lanceolate or linear*, 10—30 × 0·5—2 *cm., margins wrinkled. Osier.*

Salix viminalis sometimes has minute distant teeth, and may then come here. See p. 286.

▱ ▱ *Leaves lanceolate, serrate, at most* 6—12 × 1—2 *cm. Tree.*

Salix alba, L. White Willow. Large tree, often pollard, with leaves much like those of *S. fragilis*, but silvery white beneath, and twigs not brittle at the joints. Leaves broad- to linear-lanceolate, 5—6 times as long as broad, 6—10 × 1—2 cm., broadest at or above the middle; straight acuminate, finely serratulate, with straight gland-

tipped teeth, and tapering sub-sessile base. When young densely silky, but may be later glabrescent and greyish green above and silky-pubescent beneath; the hairs parallel with the midrib. Stipules small, lanceolate, pubescent, caducous: petiole short, 8—12 mm., eglandular. Stomata almost as numerous above as beneath. Autumn leaves yellow and brown.

Venation fine and pinnate-reticulate, the curved secondaries coming off at open angles and breaking up before reaching the margin, the long axes of the meshes oblique. Tertiaries numerous and tend to form cross-ties. Secondaries fairly long, especially in the middle of the leaf. Margin not reflexed, serratulate. Upper surface dark green, lower white or greyish, and silky.

[The direction of the silky hairs, parallel with the midrib and not with the secondaries, distinguishes this species from *S. viminalis*. See p. 286.

Certain varietal forms with characteristic colours of the twigs are noteworthy, of which *S. vitellina*, L., the Golden Osier, with golden yellow twigs, and *S. cœrulea*, with olive green twigs and bluish leaves, both grown as osiers, are the principal.

The chief difficulty is with *S. fragilis* and allied forms, or varieties, such as *S. Babylonica*, *S. Russelliana*, &c., especially when the leaves are old and nearly glabrous. *S. fragilis* is typically glabrous and greener, and its twigs snap at the articulations. *S. Russelliana* has the glabrous leaves of *S. fragilis*, but the twigs hardly fragile; and *S. Babylonica* has narrower glabrous leaves and the weeping habit.

S. rubra, Huds., is a variety or hybrid of *S. purpurea*, with lanceolate and often sub-opposite leaves, silky beneath, and about 6—7 times as long as broad (9—18 × 2—3 cm.); in one form known as the Rose Willow, owing to the pink bud-galls often borne by it.

Other varieties and hybrids cannot be dealt with here.]

†† Leaves not silky-pubescent, but glabrous or nearly so.

⊙ *Leaves narrow, 6—18 × 1—3·5 cm. or so: not conduplicate. Stipules broad and deciduous. Leaf-insertions broad and narrow, crescentic, extending nearly half-way round the shoot. Buds exhibiting one scale only.*

▭ *Shoots not pendent.*

§ *Twigs fragile at the joints; leaves all alternate.*

Salix fragilis, L. Crack Willow (Fig. 87). Tree, often pollard, with the twigs more divergent than those of *S. alba*, and easily snapping at the articulations. Leaves, except those first emerging or on the catkins, narrow lanceolate, and long acuminate, 6—18 × 1·5—3·5 cm. (about 5 times as long as broad), broadest below the middle, and somewhat oblique, rather coarsely glandular serrate; on short petioles (usually about 5—15 mm.), at length glabrous, bright green above and paler or bluish beneath, often with light-coloured midrib and distinct venation. The first leaves may be entire, ovate or rounded, and ciliate or silky. The petiole may reach 2·5 cm. and have two glands above. Usually rather tough, the acuminate point oblique. Stipules of vigorous shoots semi-cordate or reniform and coarsely toothed, obtuse, appressed, deciduous; but often obsolete on other shoots. Stomata few above and about a quarter as many beneath. Autumn leaves yellow and brown.

Venation like that of *S. alba*, but secondaries often leaving the midrib at more acute angles, about 45°.

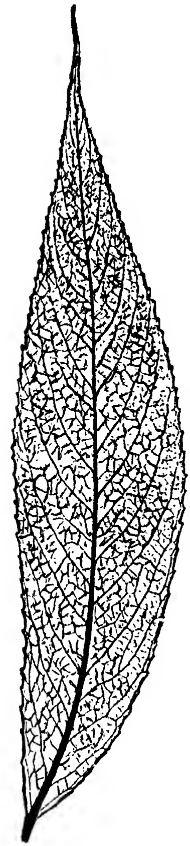

Fig. 87. Crack Willow, *Salix fragilis*, p. 246 (Ett).

S. Russelliana, the Bedford Willow, appears to be a hybrid with *S. alba*. The slender shoots bear leaves which resemble those of *S. fragilis* in shape and toughness, and in being at length glabrous, pure green, &c.; while

they approach *S. alba* in the straight acuminate point, silkiness when young, and hardly fragile twigs.

§§ *Twigs not fragile at the joints; leaves sub-opposite.*

Salix purpurea, L. Purple Osier. The leaves are not always opposite, but the sub-opposite condition prevails; and the stipules are frequently absent. See p. 178.

▭ ▭ *Shoots pendent: twigs not fragile at the joints.*

S. Babylonica, L. Weeping Willow. Weeping tree, with very slender pendent shoots. Leaves $7—16 \times 1—2{\cdot}5$ cm., narrow to linear-lanceolate, with long drawn and oblique point, finely and sharply serrate, quite glabrous and dark green at least above, or bluish beneath. Petiole short, 5 mm., hairy above; stipules minute, lanceolate or sickle-shaped, serratulate, caducous. Upper stomata few. Venation as in *S. fragilis*.

[The leaves of *Salix triandra* and *S. daphnoides* are also sometimes more or less lanceolate, and may then be looked for here, though they are usually broader. *S. daphnoides* is usually easily distinguished by its purple twigs and waxy bloom. See p. 278. *S. triandra* has large stipules, and the leaves deep shining green above and glaucous below. See p. 278.

The leaves of *S. nigricans*, which dry black (see p. 292), and those of the rare Alpine species *S. Lapponum* (p. 288) and *S. Myrsinites* (p. 280), may also give trouble here when the narrow forms are met with; the two latter are dwarf and prostrate.]

⊙ ⊙ *Leaves usually broader, oblong-lanceolate to lanceolate, $4—10 \times 2—2{\cdot}5$ cm. or so: conduplicate. Stipules filiform. Leaf-in-*

sertions short and broad, elliptic, extending about $\frac{1}{4}$ round the shoot. Buds showing several scales.

Amygdalus communis, L. Almond. Small tree with slender spreading branches and glabrous shoots. Leaves lanceolate or oblong-lanceolate, sharply or obtusely serrate, the lower teeth glandular; glabrous, shining above, softly hairy beneath when young. About 4—10 × 2—2·5 cm. Flowering before the leaves appear. Petiole 15—25 mm., with four or more glands above. Leaves conduplicate. Autumn leaves red and yellow.

[The Willows can always be distinguished from *Prunus* and *Amygdalus* by their broader and narrower leaf-insertions and their buds. See p. 274.]

** Leaves not typically lanceolate; relatively broad and not more than about twice as long as wide.

† Leaves tomentose or velvety hoary beneath.

⊙ *Leaves hard, evergreen, spinescent-dentate.*

Quercus Ilex, L. Evergreen Oak, Holme Oak. Small evergreen tree with greyish foliage. Leaf ovate-oblong or ovate-lanceolate, to narrow elliptic or rounded; very variable, 3—7 × 1—3 (1—8 × 0·5—5) cm., leathery, persisting nearly three years; apex acute or obtuse, base slightly attenuate to cordate, spinose-dentate, like the Holly, on young and vigorous trees, but entire on old ones; thick, dark green, glabrous and polished above, greyish or fawn tomentose beneath, or on young trees pale and pubescent to glabrescent. Petiole 5—20 mm. Stipules linear, purplish. Dying leaves dirty brown.

Venation pinnate, on the general plan of other Oaks. Midrib often sinuous, secondaries 6—10, relatively thin

and sinuous, the lowest coming off at open angles of 80—90°, the rest at angles of 40—55°. Tertiaries nearly straight as cross-ties, at open angles. Meshwork very fine.

[The Cork Oak, *Q. Suber*, has similar leaves, but the bark is thick and corky.

The Holly is usually more lobate-toothed, quite glabrous, and shows no stipules (but see pp. 20 and 203).]

⊙⊙ *Leaves not hard and evergreen, or spinescent-toothed.*

▭ *Leaves small, about* 1—4 *cm. long; teeth very minute and distant. Plant dwarf or creeping.*

Salix repens, L. The broader-leafed forms, elliptic to broad oval or ovate, may be looked for here (see p. 243); the serratulation may be extremely minute or even absent. See p. 288.

Salix Lapponum, though usually entire, occasionally shows undulate toothing, and might then be looked for here. See p. 288.

▭▭ *Leaves larger, about* 5—10 *cm. or more long, distinctly toothed. Plant not dwarf or creeping.*

§ *Serrate or bi-serrate, teeth small; venation pinnate, or pinnate-looped and reticulate.*

♯ *Simply serrate; venation pinnate-looped and reticulate.*

Pyrus Malus, L. Apple (Fig. 88). Small tree with leaves tufted on the dwarf shoots. Leaves broad and short, ovate or oval to oblong-ovate, 4—10 × 3—6 cm., acute or acuminate, serrate or crenate-serrate, tough, glabrous or nearly so in some forms but typically shining above and

hoary or velvety beneath. Not blackening on drying. Petiole not exceeding half the length of the midrib, 1—5 cm. Stipules subulate, downy, deciduous. Autumn leaves brownish.

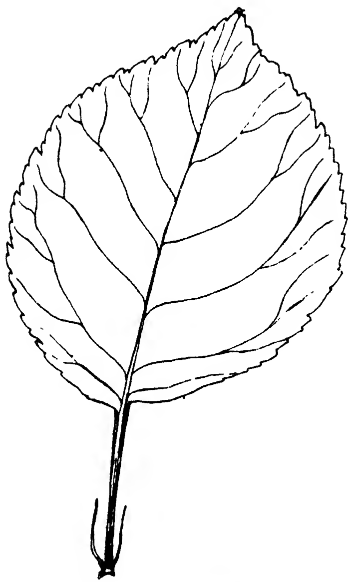

Fig. 88. Apple, *Pyrus Malus*, p. 250 (D).

Venation pinnate-looped and reticulate. About half-a-dozen strong secondaries leave the midrib on either side and curve forwards at about equal angles of 45° or so, as if pinnate; but they soon loop and become reticulate, with secondary loops superposed between them and the margin, the smaller veins ending in the teeth. Each pair of secondaries in mid-leaf about $\frac{1}{5}$—$\frac{1}{4}$ the length of the midrib apart. Tertiaries leaving the secondaries at more acute angles on the inner than on the outer side, and tending to

form cross-ties: they are fairly strong, those of the outer side of the lower secondaries particularly so, transverse and close. The veins of higher orders very fine.

[The leaf of the Pear is tomentose when young, but becomes glabrous or nearly so: it has a finer and more prominent reticulation and a longer, more slender petiole, and the dwarf shoots tend to be thorny. See p. 274.]

Doubly serrate, teeth large and sharp; venation pinnate, with the secondaries running straight to the margins, and giving off strong outer branches and forks.

Pyrus Aria, Ehrh. White Beam (Fig. 89). Medium tree, with very white undersides to the leaves. Leaf

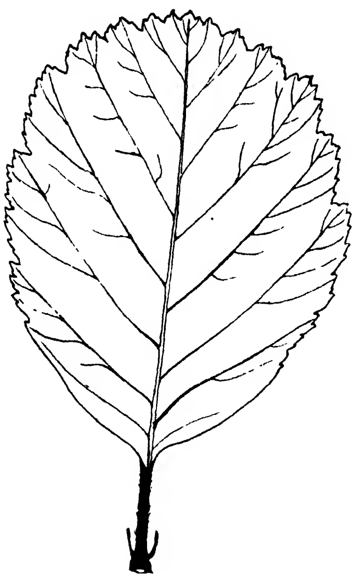

Fig. 89. White Beam, *Pyrus Aria*, p. 252 (D).

6—9 × 3—7 cm., ovate, elliptic or obovate; narrower, rounder or slightly cordate at base, acute or obtuse; sharply bi-serrate, or cut into larger teeth, or irregularly incised into rounded lobes and pinnatifid, or in rare cases pinnatisect and even compound at the base. Grey-arachnoid when young, becoming deep green, glabrous and shining above, white-tomentose beneath. Plicate when young. Petioles about $\frac{1}{5}$ the length of the limb, 1—2 cm. long. Autumn leaves yellow and brown, often passing through brilliant ochre, tawny yellow and even orange-scarlet tints to coppery browns.

Venation pinnate, the strong secondaries running nearly straight to the margin and terminating in the teeth: most of them sending out forks or branches from their outer sides, which similarly end in teeth. Tertiaries fine, close and transverse, leaving the secondaries at obtuse angles on their inner, at acute angles on their outer sides, and forming more or less developed, very delicate cross-ties and network. Secondaries about $\frac{1}{8}$ the length of the midrib apart, their outer branches prominent, especially those from the lower secondaries. Tertiaries almost straight as cross-ties.

§§ *Leaves blunt- or crenate-serrate or sinuate-toothed.*

‡ *Venation pseudo-palmate at the base; irregularly and coarsely sinuate-dentate, with large blunt triangular teeth. Leaves not rugose. Shoots not nodose.*

÷ *Petioles 2—3 cm. long, terete or compressed.*

Populus alba, L. Abele. The leaves of weak shoots and old trees may be rounded, rhomboid-ovate or oblong,

with irregular, coarse, broadly triangular blunt teeth, passing to sinuate-lobed. See p. 208.

÷ ÷ *Petioles* 3—8 *cm. long, compressed.*

8 *Buds not viscid; but, like the petioles and shoots, velvety or cottony.*

Populus alba, var. *canescens*. Grey Poplar (Fig. 90). Moderate-sized tree. Leaves thin, rounded-ovate, rounded-deltoid, or nearly heart-shaped, to sub-orbicular, angular

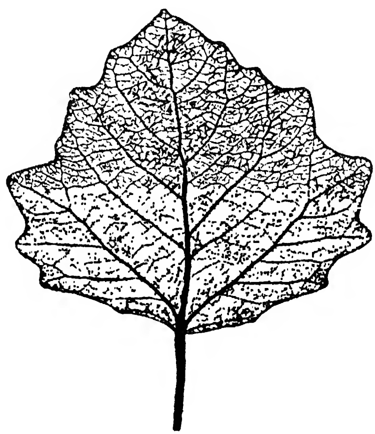

Fig. 90. Grey Poplar, *Populus alba*, v. *canescens*, p. 254 (Ett).

or coarsely sinuate-dentate into irregular blunt triangular teeth; grey-tomentose or silky-woolly beneath, with greyer tomentum than in *P. alba*, becoming more or less glabrous as the leaf ages; bluntly acuminate, about 5—6 cm. diameter (5—8 × 5—6·5 cm.), or, on strong suckers up to 10—12 × 8 cm. Autumn leaves yellow and brown.

Venation pseudo-palmate. The two lowest secondaries

(basal ribs) are nearly or quite as strong as the midrib, and radiate from its base into the lamina, where the midrib then gives off pinnate secondaries nearly as strong. Basal ribs and their outer veins converging upwards. Outer veins of basal ribs perpendicular to the midrib, and straight or but little curved upwards. Tertiaries principally developed as cross-ties. See p. 208.

8 8 *Buds viscid, and like the petioles and shoots glabrous.*

Populus tremula, L. Aspen. The smaller ordinary leaves, though pubescent when young, become quite glabrous on both faces, non-shining, and are nearly round and on long slender petioles, trembling with the slightest movement of the air. See p. 264.

‡‡ *Venation pinnate-looped and reticulate, not pseudo-palmate; prominent below and the leaf rugose. Teeth small, crenate-serrate. Shoots nodose.*

÷ *Shoots pubescent, but not velvety or tomentose; buds glabrous.*

8 *Leaves usually at least* 6 *cm. long, more or less ovate, and glabrous above.*

Salix Caprea, L. Goat Willow, Sallow (Fig. 91). Shrub with grey or silvery shoots and foliage. Leaves broad, elliptic to rounded ovate, or oblong; or more or less rounded oblong to oblong-obovate or oblong-lanceolate, 6—9 cm. (3—7 × 2—5 cm., or even up to 10—14 × 6—10 cm.) long. Obtuse or acute, or acuminate with slightly oblique point, and may be slightly cordate or attenuate below. Margin crenate, or almost entire, more or less undulate and recurved. Young leaves silky-velvety, be-

coming glabrous or glabrescent, darker green, and rugose above; white or bluish hoary or tomentose beneath, with crisp not silky down, and prominent reticulate venation.

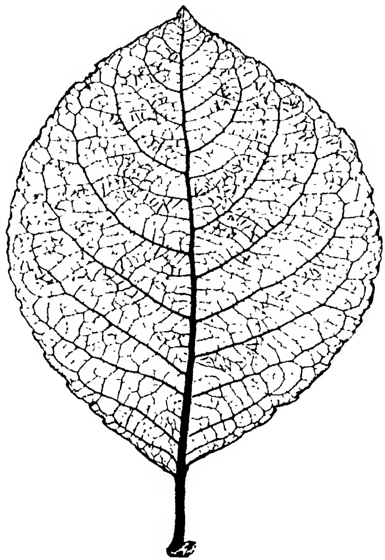

Fig. 91. Sallow, *Salix Caprea*, p. 255 (Ett).

Petiole short, 1—2 cm., more or less tomentose. Stipules usually large, oblique reniform dentate, deciduous. Buds at length smooth. Autumn leaves yellow to brown.

Venation like that of *S. nigricans*, but usually more prominent beneath and sunk above, and the leaf elliptical or rounded ovate and broader. There are no stomata above.

[*S. Caprea*, var. *cinerea*, has usually narrower lanceolate-obovate leaves, tapering below, and about 5—12 × 2—5 cm.; but they vary to oblong or oblong-obovate to obovate;

or elliptic- to oblong-lanceolate; acute or shortly acuminate, and more tomentose shoots, buds and leaves, the latter especially grey-tomentose or reddish on old leaves beneath. Venation as in *S. Caprea* and even more prominent, and rugose. The margins are usually undulate and serratulate and the lamina pubescent above. Petiole pubescent, dilated below, and about 1 cm. long. Stipules large, half-reniform, toothed, and long persistent on strong shoots. No upper stomata.]

8 8 *Leaves usually small, about* 2—5 *cm. long, obovate, greyish pubescent above. Stipules large.*

Salix aurita, L. Eared Willow (Fig. 92). Shrub with villous shoots and grey foliage. Leaves softer and smaller

Fig. 92. Eared Willow, *Salix aurita*, p. 257.

than in *S. Caprea*, 3—4 cm. long (2—7 × 1—3 cm.); and obovate or oblong-obovate, but may be oblong to sub-rotund; cuneiform below, acute, obliquely cuspidate or obtuse. Edges slightly revolute, wavy, toothed, crenate or nearly entire. Dull grey green and downy above, and much wrinkled; grey or bluish tomentose, and strongly yellowish reticulate beneath. Petiole 4—8 mm. long, sub-tomentose. Stipules large, half-cordate, often toothed, and persistent. Buds smooth. Autumn leaves yellow.

Venation like that of *S. Caprea*, but leaves more obovate. There are no stomata above.

†† Leaves not tomentose or velvety hoary beneath; glabrescent or glabrous.

⊙ *Venation strict-pinnate, the secondaries running straight to the teeth of the bi-serrate margin. Leaves broad, more or less glandular viscid, and buds resinous or viscid.*

▭ *Leaf deep green, broadly obovate; secondary ribs 6—8 pairs, the lower the shortest.*

Alnus glutinosa, Gaertn. Alder (Fig. 93). Medium tree with trigonal shoots, stalked buds, and dark shining foliage in $\frac{1}{3}$ spiral. Leaf about 4—9 × 3—7 cm. (4—10 × 3—9), rounded, broadly obovate, or nearly obcordate, to orbicular-cuneate, ovate-elliptic or sub-orbicular; obtuse, truncate, or slightly retuse at apex, and with cuneiform base; irregularly sinuous or slightly lobed and bi-serrate or dentate, or nearly entire below. Glabrous and deep shining green above, and more or less viscous, hardly paler, finely glandular beneath, and with tufts of rusty hairs on the midrib and in the axils of the veins. Petiole rather short, 1—2 cm., pubescent. Stipules conspicuous, blunt,

ovate to lanceolate, fringed with glandular hairs. Young leaves viscid above. Autumn leaves deep brown to black.

Venation strict-pinnate, the midrib straight, strong below, tapering to a capillary end; secondaries 5—7 pairs, straight or the lower slightly diverging to the margin and

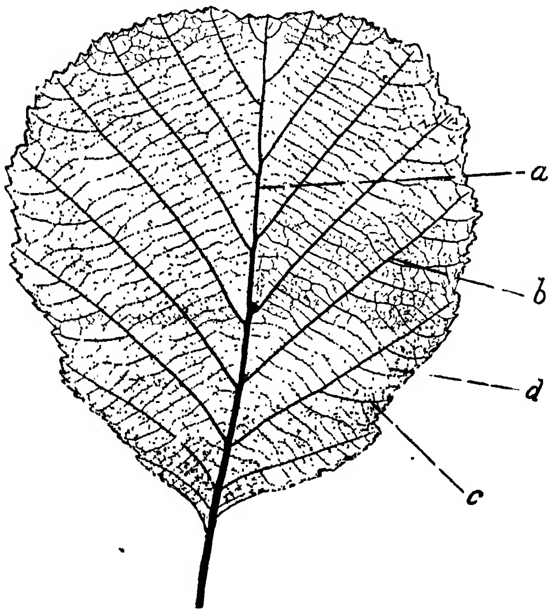

Fig. 93. Alder, *Alnus glutinosa*. Venation strict-pinnate. *a* midrib; *b* secondary; *c* tertiary; *d* quaternaries and terminals forming network, p. 258 (Ett).

ending in teeth, or mostly forking at the apex, or giving off strong outer nerves, which do so: angle 50—65 degrees. Tertiaries at acute angles, sinuous, not looped beneath the bi-serrate margin, and often forming complete cross-ties before anastomosing. Each pair of secondaries distant

about ¼ the length of the midrib; the lowest much shorter than those in the middle of the leaf, and more divergent, and they are almost devoid of conspicuous outer nerves. Meshes rather loose, not prominent.

□□ *Leaf triangular- or rhomboid-cordate or broad-ovate, acuminate; secondaries* 5—6 *pairs, the lower the longest.*

Betula alba, L. Birch (Fig. 94). Small tree, with white periderm, and slender more or less drooping shoots,

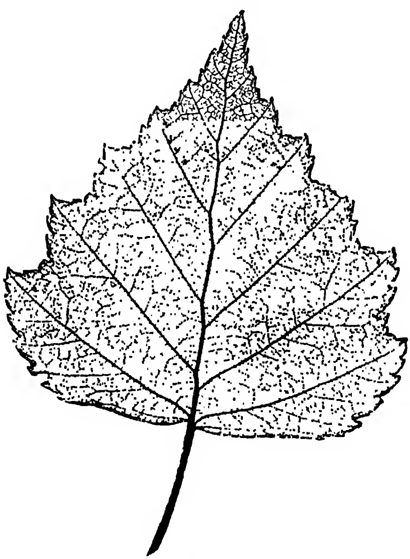

Fig. 94. Birch, *Betula alba*, p. 260 (Ett).

bearing thin foliage. Leaf variable, 4—6 × 2—5 cm. (3—9 cm.), broadly deltoid- or rhomboid-cordate to ovate-triangular, or more or less broad-ovate to broadly cuneate; with plane or angular-rounded, or rarely truncate or

slightly cordate base, and tapering acuminate apex. Margin more or less angular or sinuate-serrate with large teeth again serrate or bi-serrate; entire at the base. Membranous to sub-coriaceous, green and somewhat shining; paler and glandular, dotted and viscid below, especially when young. Slightly pubescent when young, usually becoming glabrous. Stipules broad and conspicuous. The leaf is often hung so lightly as to tremble like the Aspen. Petiole about 2—3 cm., half as long as the midrib. Autumn leaves bright yellow, orange and reds passing to brown.

Venation strict-pinnate, midrib tapering from a stout base, straight or somewhat zigzag to the apex: the secondaries running, slightly curved, direct to the margins and ending in teeth or lobes. Tertiaries fine and connecting, coming off at acute angles on both sides; not looped beneath the irregularly serrate margins. Each pair of secondaries separated by a distance about equal to $\frac{1}{5}$ the length of the midrib; upper secondaries simple, coming off at angles of 40—50 degrees; the lower the longest and at angles of 60—75 degrees, and with several prominent outer branches. Reticulation distinct, meshes chiefly oval.

[Several varieties occur, differing in the details of size, shape, toothing and pubescence, viscidity, &c. of the leaves, more or less drooping habit and so forth.]

Betula nana, L., the Dwarf Birch, is an Arctic shrub, with erect shoots and dark green, very small, sub-orbicular, glabrous leaves, usually broader than long, 5—10 × 6—12 mm. (4—12 × 5—15 mm.), crowded, obtuse, coarsely crenulate-dentate, glabrous, with venation reticulate and salient and gland-dotted below, and sub-sessile or on very short petioles (1—2 mm.). Secondaries 2—4 pairs. Otherwise similar to *B. alba.*

⊙ ⊙ *Venation not strict-pinnate. Leaf neither viscid-glandular, nor sharply bi-serrate.*

▱ *Venation pseudo-palmate at the base, the lower secondaries longest: reticulation marked. Buds viscous. Petioles compressed.*

§ *Leaves broad, deltoid or sub-rhomboid acuminate; hardly paler beneath; margin cartilaginous and coarsely serrate. Stomata above as numerous as beneath.*

♯ *Shoots terete or nearly so.*

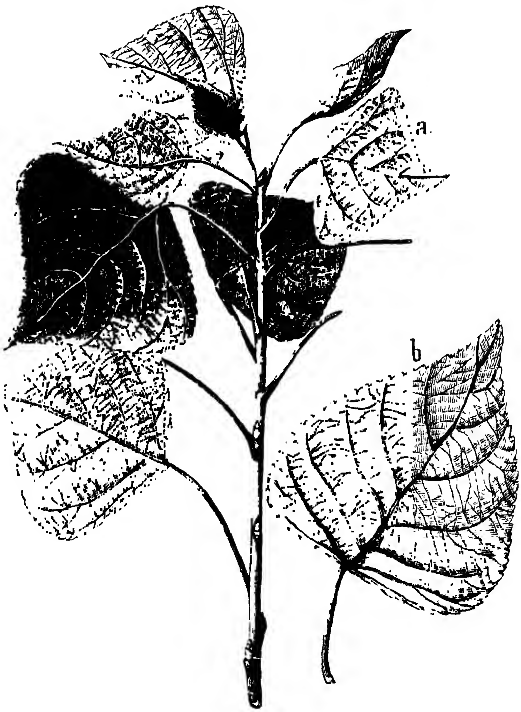

Fig. 95. *a* Black Poplar, *Populus nigra*; *b Populus Canadensis*, p. 263 (Sc).

Populus nigra, L. Black Poplar (Figs. 95 and 96). Large tree, spreading or (var. *pyramidalis*) fastigiate, with loosely hung foliage. Leaves triangular- or sub-orbicular-

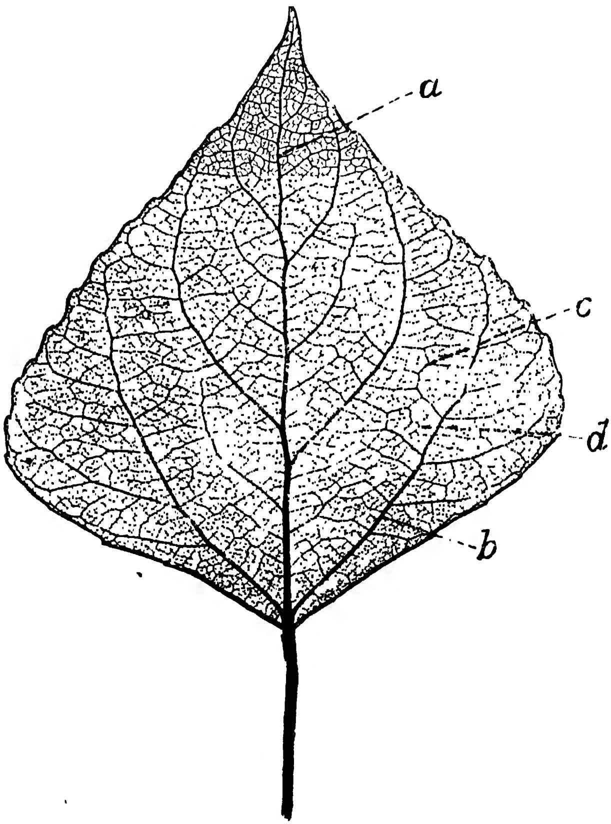

Fig. 96. Black Poplar, *Populus nigra*. Venation pinnate with pseudo-palmate base. *a* midrib; *b* basal secondary; *c* tertiaries; *d* network of terminals, &c., p. 263 (Ett).

cordate, to deltoid, or broad-ovate, tapering acuminate; often sub-rhomboid and broader than long, 5—10 cm.

(1·5—10 × 2·5—6 cm.) diameter. Base straight, or slightly cordate or feebly cuneiform with the lower angles rounded: regularly and closely crenate-serrate, with blunt and thickened teeth. Firm, glabrous, green and somewhat shining on both sides (often yellowish green), or paler matt green beneath. Petioles 3—6 cm., compressed, somewhat shorter than the lamina. Young leaves yellowish, covered with deciduous hairs, somewhat silky ciliate and viscous, as are the buds. The petiole and principal veins often red. The leaves on strong suckers may attain 14—16 cm. diameter. Autumn leaves yellow and brown.

Venation like that of *P. tremula*, but the meshes irregularly angular, loose and distinct but not very prominent.

‡‡ *Shoots angular and grooved.*

Populus Canadensis, Desf. Canadian Poplar. Very similar to the preceding, but the leaves more ciliate, especially when young, and pubescent on the veins beneath, the shoots more angular. Buds viscous. The leaf varies from 6—12 × 5—10 cm. up to 12 × 13 cm. Petiole pubescent, 3—5 cm. long.

§§ *Leaves more or less sub-orbicular. Distinctly paler beneath and devoid of stomata above. Margins not cartilaginous, bluntly crenate-serrate.*

Populus tremula, L. Aspen. Small tree, with pendent trembling leaves and pubescent suckers and buds. Leaf thin and herbaceous, rounded-ovate to sub-orbicular, 3—7 × 3—8 cm., on petioles 3—6 cm. long; or, on strong shoots or suckers, much larger, up to 10—15 cm., and more (14—19 × 12—13·5 cm.), ovate, cordate, on petioles up to 8 cm. long; or triangular with rounded

angles, and on shorter petioles. The larger leaves nearer the apex. Obtuse to acuminate, strongly sinuate-dentate, with blunt broad teeth, or more or less obtusely-serrate or crenate-serrate, with incurved teeth. The smaller ordinary leaves softly pubescent beneath and on the veins above when young, and the petiole grey-tomentose; becoming glabrous and matt green above, with yellowish venation, and nearly white or glaucous beneath with prominent venation. The larger leaves grey velvety beneath, and sometimes above also. Petioles very slender and compressed, rarely glandular above, glabrous. Suckers and young shoots pubescent. Buds viscid. The cordate leaves of long shoots may be nearly entire. Autumn leaves yellow and brown, often passing through brilliant chrome yellow, orange to purplish scarlet or crimson hues, to red-brown.

Venation pinnate and pseudo-palmate, the two lowest secondaries (basal ribs) leave the midrib at the junction of the petiole, and extend radially right and left, the midrib then giving off pinnate secondaries further up. Basal ribs, like the other secondaries, somewhat feebler than the midrib; they and their outer tertiaries converging slightly upwards, the latter almost perpendicular to the midrib in general direction. Tertiaries predominantly anastomosed into small but well-developed rather rounded meshes; secondaries distinctly sinuate. Reticulation prominent.

□□ *Venation pinnate-looped or reticulate. Buds not viscous.*

§ *Leaf-insertion narrow and rounded; leaf-scar elliptic, extending not more than ¼ way round the shoot.*

♯ *Shoots spinescent with true thorns, more or less pubescent. Petioles eglandular: stipules linear and persistent. Leaves convolute.*

Prunus spinosa, L. Blackthorn (Fig. 97). Shrub with thorns, and slender downy pubescent shoots, flowering before the leaves open. Leaf 3—6 × 1—4 cm., ovate or oblong-ovate, to obovate, obovate-lanceolate, elliptic or broadly lanceolate; tapering to the petiole, acute, irregu-

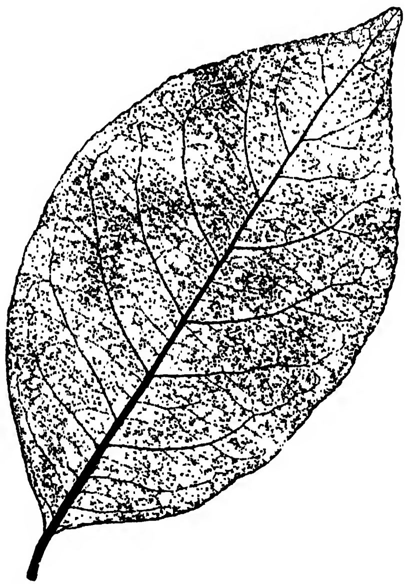

Fig. 97. Blackthorn, *Prunus spinosa*, p. 266 (Ett).

larly and finely serrate or bi-serrate; variable in size and acuteness, those tufted on the dwarf shoots often obtuse. Pubescent, or becoming glabrous above and pubescent only on the veins beneath. Petioles 5—10 mm., eglandular. Leaves convolute in bud. Autumn leaves yellow to reddish.

Venation pinnate-looped and reticulate. The midrib

gives off about half-a-dozen weak secondaries at somewhat acute angles on each side; these curve forwards and soon loop and break up, and have secondary loops superposed on them, beneath the margin. Network abundant, and loops distinct. Each pair of secondaries in mid-leaf, about $\frac{1}{4}$ the length of the midrib apart. Angles of divergence about equal, 40° or so. Ends of tertiaries, &c. terminating in teeth. Tertiaries from the outside of the secondaries at more acute angles than those from the inner sides.

[The following varieties, or sub-species, are noteworthy, and it will be seen that they carry the species into the non-spinescent forms: even *P. spinosa* itself is sometimes devoid of the thorns, and it should be noted that the Pear (see p. 274) may have its dwarf shoots hard and sharp, like thorns: it is distinguished by its long eglandular petioles, more rounded and very reticulate leaf, and extended narrow crescentic leaf-insertions. The young leaves are also involute and the shoots glabrous.

Prunus insititia, L. Bullace (Fig. 98). Small tree with velvety-pubescent, and somewhat spinose, slender shoots; flowering before or with the leaves. Leaf broad-ovate, ovate-lanceolate, elliptic or oblong-obovate, acute, serrate, softly pubescent, especially on the venation beneath, becoming glabrous above, 4—6 × 2—3 cm. Stipules linear, pubescent. Leaf convolute in bud. Petiole 5—10 mm.

Prunus domestica, L. Plum (Fig. 99). Small tree with slender, glabrous and non-spinescent shoots; flowering with the leaves. Leaf shorter and broader, elliptic or oblong, obovate, acute, crenulate-dentate or bi-serrate; pubescent beneath, especially on the veins, becoming

glabrous above and slightly rugose. Petiolate; stipules linear and persistent. Young leaves convolute.]

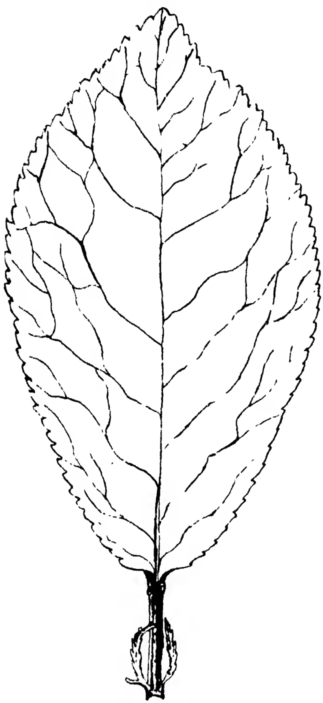

Fig. 98. Bullace, *Prunus insititia*, p. 267 (D).

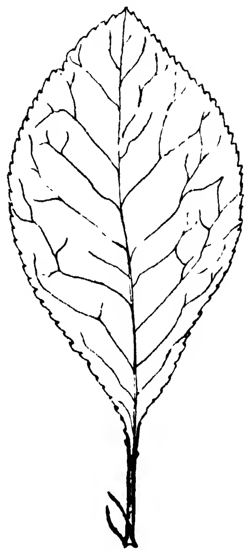

Fig. 99. Plum, *Prunus domestica*, p. 267 (D).

‡‡ *Shoots devoid of thorns.*

÷ *Petioles glandular at the top.*

8 *Leaves softly pubescent beneath, and pendent; conduplicate.*

Prunus Avium, L. Gean (Fig. 100). Large tree with satiny and peeling, sub-verticillate branches, and leaves

tufted on dwarf shoots along the branches. Leaves large (5—12 × 4—6 cm.), pendent, ovate or obovate, to elliptic, or oblong-obovate; acuminate, sharply serrate or bi-serrate

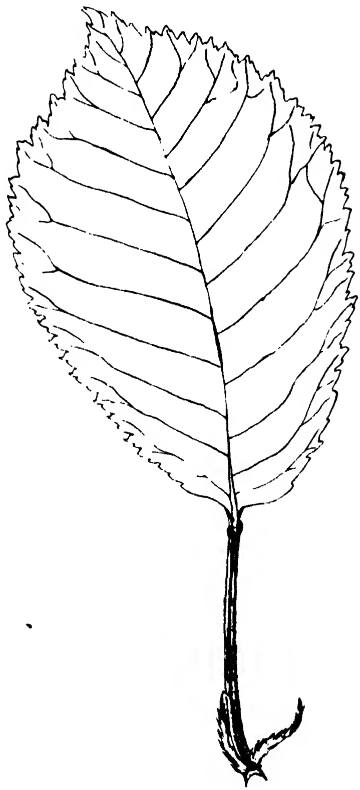

Fig. 100. Gean, *Prunus Avium*, p. 268 (D).

with glandular teeth; thin, herbaceous, soft, slightly plicate or rugose, matt green above, paler and softly velvety-pubescent beneath, especially on the veins. Petiole

1—3 cm., with 2 reddish glands above. Flowers with the leaves, which are conduplicate in bud. A variety or sub-species of *P. Cerasus.* Autumn leaves passing through fine orange-reds or rich yellows to pink and crimson reds and browns.

Venation pinnate-reticulate, with little tendency to looping. The midrib gives off about 10 secondaries on each side, pinnate at open angles, but soon breaking up beneath the margins, the forking more conspicuous than the looping, and the ends of the tertiaries and smaller veins passing into the teeth. Reticulation abundant. Each pair of secondaries distant about $\frac{1}{12}$—$\frac{1}{8}$ the length of the midrib. The outer tertiaries leave the secondaries at acute, the inner at obtuse angles, and tend to form nearly transverse cross-ties.

[Forms of *P. Cerasus* with the petiolar glands developed may be looked for here, but the leaves are glabrous, or nearly so, and not soft and pendent.]

§ § *Leaves glabrous or nearly so, and not pendent. Shoots glabrous.*

△ *Leaves oblong-lanceolate to lanceolate, conduplicate.*

Amygdalus communis, L. Almond. Forms with the leaves less pronouncedly lanceolate may be looked for here. See p. 249.

△△ *Leaves elliptic-ovate, or oblong-obovate, &c., convolute.*

Prunus Padus, L. Bird Cherry (Figs. 101 and 102). Small tree with sub-verticillate branches, and flowering with the leaves. Leaf large, 6—12 × 3—7 cm., ovate to ovate-lanceolate, obovate or elliptic, somewhat oblique-

cordate at the base, acute or acuminate, finely and sharply serrate or bi-serrate, the teeth not glandular. Deep matt green, glabrous and slightly rugose above, paler beneath or

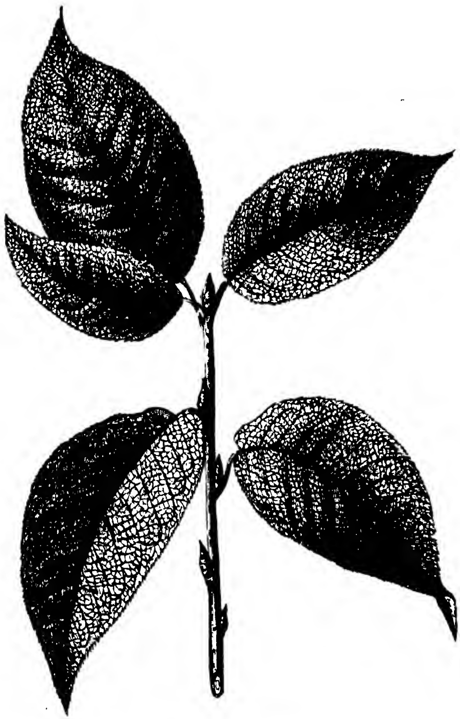

Fig. 101. Bird Cherry, *Prunus Padus*, p. 270 (Sc).

glaucous, and slightly pubescent in axils of veins. Petiole 10—15 mm., as a rule bi-glandular above. Young leaf convolute. Stipules subulate, glandular-toothed. Autumn leaves greenish yellow to reddish.

[These closely-allied species of *Prunus* are distinguished as follows. The leaves of *P. Cerasus* are narrower and more lanceolate, and more taper-based than those of *P. Padus*, and irregularly crenate-serrate; those of the

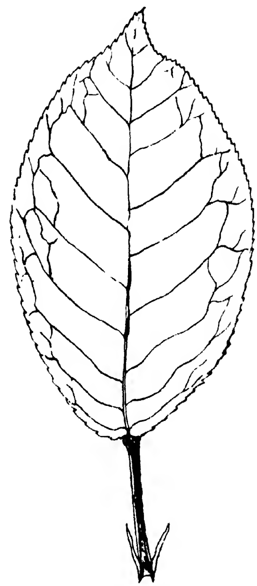

Fig. 102. Bird Cherry, *Prunus Padus*, p. 270 (D).

latter are broader and more elliptical or ovate, acutely bi-serrate and somewhat obliquely cordate at the base. The leaves of *P. Avium* resemble those of *P. Cerasus*, but droop more as if flaccid instead of firm and erect.

Other species with glands on the petioles are *Salix pentandra* and *Viburnum Opulus*. *Prunus Laurocerasus* has glands on the lower part of the lamina.]

÷ ÷ *Petioles eglandular.*

8 *Leaves conduplicate.*

Prunus Cerasus, L. Cherry (Fig. 103). Small tree with slender, spreading, and somewhat pendent shoots. Leaves 6—12 × 34 cm., ovate, ovate-lanceolate, oblong-

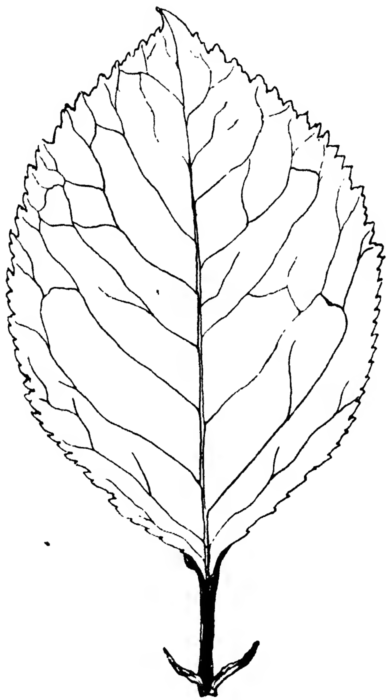

Fig. 103. Cherry, *Prunus Cerasus*, p. 273 (D).

ovate or -obovate, to elliptic or oblong; abruptly acuminate, bi-serrate or irregularly crenate-serrate with glandular teeth; firm above, paler matt green beneath; glabrous or

sub-coriaceous, not pendent, dark shining green, slightly pubescent when young. Petiole eglandular, or occasionally with 1—2 glands at the top or on the base of the lamina. (See p. 270.) Autumn leaves red and yellow. Leaves conduplicate. Flowers with the leaves. Stipules subulate, often toothed and glandular, caducous.

Venation like that of *P. Avium*, the looping perhaps more pronounced.

8 8 *Leaves convolute.*

Forms of *Prunus spinosa*, devoid of thorns, and of its varieties *P. insititia* and *P. domestica*, may be looked for here. See p. 267. Also *P. Padus*, when the petiolar glands are, as sometimes occurs, obsolete. See p. 271.

[Several of these species of *Prunus* have resemblances, more or less, to certain *Willows*; but the numerous scales to the buds and the narrower leaf-insertions at once distinguish them. See p. 276.]

§§ *Leaf-insertion long and narrow, crescentic, and extending about half-way round the shoot.*

‡ *Leaves involute in bud; dwarf shoots sharp or even thorn-like; buds with several scales.*

Pyrus communis, L. Pear (Fig. 104). Medium tree, with leaves scattered on the long shoots, fascicled on the often thorn-like dwarf shoots on older branches. Leaves ovate or obovate to oblong-ovate, ovate-lanceolate, oblong, elliptic or sub-rotund, about 3—5 cm. long (3—10 × 3—6 cm.); shortly acuminate to obtuse, finely obtusely serrate or almost entire, especially at the base, which may be rounded, or rarely slightly cordate or attenuate; somewhat tomentose when young, becoming glabrous, or occasionally

glabrescent, sub-coriaceous, shining dark green above, paler and with fine reticulation beneath. Black when dried, but autumn leaves rich yellow or reddish yellow. Petiole slender, 2—7 cm., and usually as long as the midrib, glabrous or pubescent. On young trees the leaves may show signs of lobing.

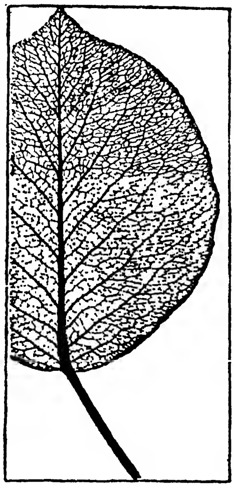

Fig. 104. Pear, *Pyrus communis*, p. 274 (Ett).

Venation beautifully reticulate. The midrib gives off about half-a-dozen weak, short, sinuous secondaries on each side, starting as if pinnate, but rapidly looping and breaking into a fine distinct network. Tertiaries off at acute angles. Lowermost secondaries at more open angles than the upper: medium about 40°.

[The Apple rarely has sharp dwarf shoots, and the leaf is usually hoary beneath, the petiole shorter, and the venation less reticulate. See p. 250.]

‡‡ *Leaves not involute, and buds with only one scale; dwarf shoots not thorn-like.*

÷ *Petiole glandular. Leaves polished and large. Erect shrub. Shoots neither violet nor covered with waxy bloom.*

Salix pentandra, L. Bay Willow (Fig. 105). Glabrous shrubby tree. Leaves broad elliptic-ovate to ovate- or obovate-lanceolate; or oblong or broadly lanceolate, 6—10 × 3—5 cm. (3—15 × 1—5 cm.), viscid when young, then sub-coriaceous, quite glabrous, and very brilliant green, paler and reticulate beneath. Suddenly acuminate. Densely and somewhat obtusely glandular-serrate. Fragrant, with a faint Laurel-like odour. At most three times as long as broad, generally less. Petioles short, about 1 mm., with black or green glands, two of which represent stipules, and are ovate or oblong-lanceolate, erect and gland-toothed and caducous; but the stipules may be obsolete. The leaves are thicker and more glabrous and shining than is usual in Willows, and these characters, their shape and the petiolar glands combine to make them resemble the leaves of a *Prunus*. Midrib yellowish. There are no stomata above. Autumn leaves yellow.

Venation like that of *S. alba* and *S. fragilis*, but the secondaries loop within the margin, and the tertiaries are long and more prominent as cross-ties.

[The leaf-insertion is extended and narrow, crescentic, a peculiarity useful, in conjunction with the buds, which show several scales visible even in summer, in distinguishing the somewhat similar leaves of *Prunus*. See p. 274.

When the petioles of *S. daphnoides* and *S. fragilis* develope glands, as sometimes happens, they will come here. See pp. 246 and 278.]

Fig. 105. Bay Willow, *Salix pentandra*, p. 276 (Sc).

÷ ÷ *Petiole eglandular. Leaves not especially brilliant.*

8 *Erect and often large shrubs.*

△ *Twigs deep purple-violet and covered with waxy bloom.*

Salix daphnoides, Vill. Violet Willow. Shrub with deep violet twigs covered with waxy bloom, and brilliant yellow within the cortex. Leaves elliptic-lanceolate to oblong- or linear-lanceolate, about 4—8 × 1—3 cm. (6—15 cm.), 3—4 times long as broad; long- or short-acuminate, with recurved, acutely and minutely glandular-serrate margins. More or less silky when young, then glabrous, tough, flat, green and shining above, glaucous or bluish beneath: midrib yellowish. Petiole rather long (1—2 cm.), broad below, puberulent, fawn-coloured like the midrib, usually eglandular. Stipules half-cordate or ovate, gland-toothed, pointed, adherent to the petiole. The leaves are somewhat like those of *S. pentandra*. Stomata on the upper surface few and scattered. Autumn leaves yellow.

[Other shrubs with brilliant yellow pigment in the cortex are, *Berberis* (p. 282) and *Rhamnus* (p. 291).]

ΔΔ *Twigs not purple or covered with waxy bloom.*

Salix triandra, var. *amygdalina*. Almond Willow (Fig. 106). Shrub. Leaves oblong-lanceolate to lanceolate, or oblong-elliptic, 6—10 × 2—3 cm. (5—13 × 1—3 cm.), 3—5 times long as broad, suddenly acuminate; base rounded, margins nearly parallel. Very glabrous, even when young; tough, sub-coriaceous, deep shining green above, paler and duller or nearly white, matt or glaucous beneath, the midrib prominent and fawn-coloured. Finely glandular-serrate. Petiole short (5—10 mm.), glabrous, and grooved above. Stipules on strong shoots large and broad, reniform or half-ovate, oblique, pointed, toothed, persistent. Stomata on the upper surface few or none. Autumn leaves yellow.

Venation like *S. pentandra*, midrib distinct, but the tertiaries short and feeble.

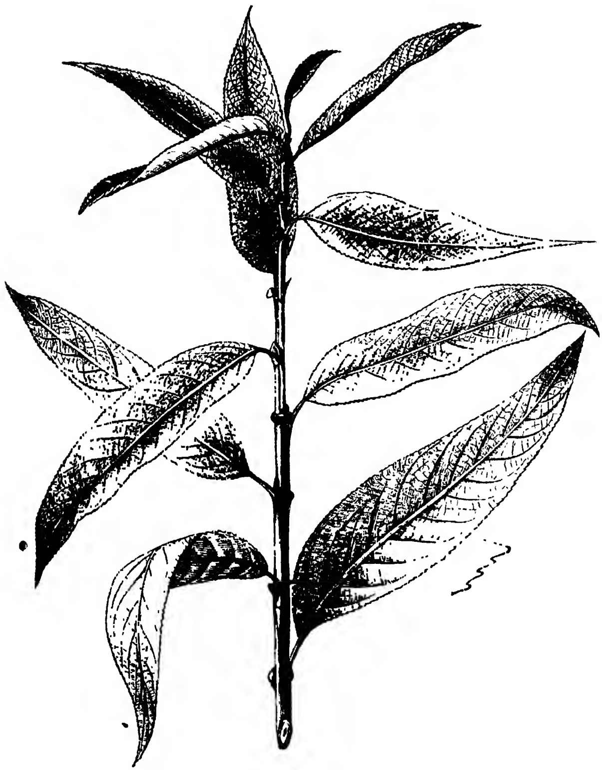

Fig. 106. Almond Willow, *Salix triandra*, p. 278 (Sc).

8 8 *Dwarf and rare, often prostrate bushes or creepers.*

△ *Leaves more or less ovate to obovate, twice to two and a half times as long as broad: glaucous or somewhat silky beneath. Petiole very short. Rare Northern species.*

σ Venation prominent on both surfaces: stomata abundant on the upper surface.

Salix Myrsinites, L. Whortle Willow. A rare Northern prostrate bush. Leaves very variable, 3—4 cm. (12—35 × 6—18 mm.) at most; ovate, elliptic, obovate or oblong-obovate, to broad-lanceolate or sub-orbicular; attenuate below, obtuse or acute, finely glandular-serrate or nearly entire; firm and rigid, shining green, venation prominent on both surfaces, midrib yellowish; glabrous or, especially when young, with a few long silky hairs, or glaucous beneath. Petiole short, 1—3 mm. Stipules lanceolate and toothed, or obsolete. Upper stomata numerous. Autumn leaves yellow.

[The leaves bear considerable resemblance to those of *Vaccinium Myrtillus*, but the stems are not angular, and the buds, stipules, insertion and size of the leaves distinguish them.]

σσ Venation not prominent: no stomata above.

Salix Arbuscula, L. Small rare Northern creeper. Leaves variable, small, hard, about 2—4 cm. × 8—20 mm., elliptic-lanceolate or oblong-obovate, acute or acuminate, finely glandular-serrate; glabrous, dark green and shining above, glaucous and bluish, glabrous or, when young, silky beneath, with prominent veins on both sides, and yellow midrib. Base cuneiform. Stipules minute or obsolete. Petiole short. Closely allied to *S. Myrsinites*, but differs especially in being glaucous, not bright green beneath. Stomata absent above. Autumn leaves yellow.

[Glabrous forms of *S. repens* may also be looked for here. See p. 243.]

ΔΔ *Leaves sub-orbicular, or hardly longer than broad.*

Salix herbacea, L. Dwarf Willow. The smallest British woody plant, with few (2—3) leaves in tufts at the ends of the shoots; leaves rarely over 2 cm. long: rare Northern creeper. Leaves 8—20 × 7—20 mm. (1—3 cm.), oval, oblong, broad-obovate, or rounded-ovate to orbicular; obtuse or slightly retuse; base indented, finely crenate-serratulate, glabrous, green and shining on both surfaces, delicate and herbaceous or papyraceous. Venation pellucid; the reticulation prominent beneath. Stomata numerous on both surfaces. Petiole very short. Stipules minute, ovate or obsolete. Autumn leaves yellow.

(ii) Leaves exstipulate.

[See note, p. 161. The difficulty is a real one, the stipules often being so minute and caducous as easily to escape observation.]

(*a*) *Leaves spinescent-toothed; some completely converted into spines.*

Berberis vulgaris, L. Barberry (Fig. 107). Armed bush, with tufted spinescent-toothed leaves, and yellow wood. Leaves 3—8 × 1·5—3·5 cm., obovate or oblong-obovate, obtuse, attenuated below and articulated to the very short petiole (5—15 mm.): spinose-serrate or -dentate, glabrous and thin, dark polished green, paler beneath. Tufted on the dwarf shoots but scattered on the long shoots. Dwarf shoots in the axils of simple, trifid or quinate spines which are modified leaves, and may be jointed and more or less laminate and membranous below, the upper margins of the sheath prolonged into two minute stipule-like bristles: see p. 20. The leaves are

really unifoliolate compound leaves: see p. 17. Shoots brilliant yellow inside. Autumn leaves red and yellow.

Venation reticulate. The midrib soon loses itself in reticulation at the apex, giving off a few weak, obscurely pinnate secondaries, which break up long before reaching

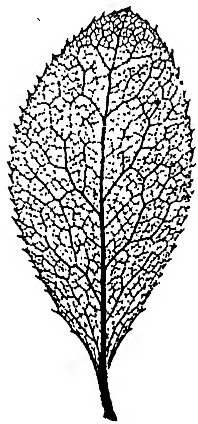

Fig. 107. Barberry, *Berberis vulgaris*. Typical reticulate venation, p. 281 (Ett).

the margins, and rapidly tend to loop, passing gradually into the close meshwork of hardly weaker tertiaries, which branch often and at open angles or rectangles. Reticulation very regular and typical.

[Other species with brilliant yellow cortex or wood are, *Rhamnus*, p. 291, *Salix daphnoides*, p. 278.

The similarly hard spinescent glossy leaves or leaflets of Holly, *Mahonia*, *Quercus Ilex* are easily distinguished.]

(β) *Spines quite absent. Leaves small, usually less than* 6—9 *cm. long.*

* Shoots and petioles glandular hairy, the former not angular.

† Leaves more or less elliptic-lanceolate; not aromatic.

Arbutus Unedo, L. Strawberry Tree. Evergreen shrub with hairy-glandular twigs and petioles, red-brown cortex and persistent leaves. Leaves 4—7 × 2—3 (6—9) cm., elliptic-, oblong- or obovate-lanceolate or ovate, acutely bi-serrate, or cartilaginous serrate, coriaceous, acute, tapering below, glabrous and shining dark green above, paler beneath, sub-sessile or on short petioles 2—5 mm. Midrib prominent, often red. Venation pinnate-reticulate. Dying leaves reddish.

†† Leaves cuneate-oblong to lanceolate, toothed at the apex only; glandular and aromatic.

Myrica Gale, L. Bog Myrtle, Sweet Gale. A bush with glandular leaves, growing in open sunny bogs. Leaves 2—4 cm. × 8—15 mm. (2—10 × 0·8—2·5 cm.), coriaceous; narrow, cuneate-obovate, obovate-oblong, cuneate-oblong or -lanceolate, sub-sessile, obtuse or acute, margin slightly revolute, entire or minutely toothed towards the apex; glabrous dark matt or grey-green or glaucous above, yellowish or pale grey-green and pubescent beneath; dotted with numerous resin-glands, especially beneath. Autumn leaves fawn to purplish brown. Venation obscurely pinnate.

[The resemblances in habit, &c., to certain Willows is at once discounted by the many-scaled buds, and the glandular hairs, also the want of stipules, the leaf-insertion, &c.]

** Glabrous in all its parts; shoots strongly angular; leaves ovate or elliptical, and not more than about 30 mm. long.

Vaccinium Myrtillus, L. Whortleberry, Bilberry. Leaves thin, alternate, on a short petiole (2—3 mm.), the insertion on the angular shoots very prominent and decurrent; ovate or elliptical, acute, about 15—30 × 10—20 mm. Serratulate, pale green, glabrous. Sometimes slightly cordate at the base. Venation distinct, reticulate. Autumn leaves brilliant cherry reds and scarlet crimsons to brown.

[The leaves of the following Willows may give trouble in this section, when toothed and exhibiting no signs of stipules—i.e. the stipules are obsolete or very caducous.

Salix purpurea, usually known at once by its more or less lanceolate, sub-opposite leaves. See p. 178.

S. repens, usually known by its creeping dwarf habit and silky shoots and leaves (see p. 243): it may have to be examined in relation to the rare alpine dwarf creepers *S. Lapponum* (p. 288), *S. Myrsinites* (p. 280), *S. Arbuscula* (p. 280), and *S. herbacea* (p. 281), in which the stipules are also frequently obsolete.

S. nigricans (p. 292), and *S. phylicifolia* (p. 293) are also occasionally devoid of evident stipules.]

(b) Leaves entire, at most faintly sinuate, or with microscopic serratulæ.

[For (ii) see p. 286.]

(i) Leaves distichous on the lateral long shoots, broad oval: venation strict-pinnate.

Fagus sylvatica, L. Beech (Fig. 108). Large tree with smooth trunk and glossy foliage, giving very deep shade. Leaf 4—9 × 3—6 cm. (3—15 × 2·5—10 cm.), elliptic, ovate, or oblong-ovate; acute, sinuate or faintly sinuate-dentate along the upper two-thirds, base slightly tapering or rounded. Thin and hard, sub-coriaceous, glabrous, clear dark green and glossy above, a little paler and silky

beneath and on the veins, and ciliate, especially when young. Venation somewhat prominent beneath; plaited parallel to the veins and with silky white hairs on the veins and in angles. Petiole short, 5—15 mm., pubescent.

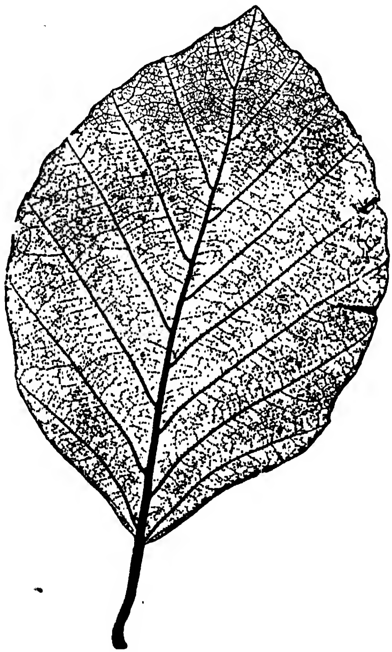

Fig. 108. Beech, *Fagus sylvatica*, p. 284 (Ett).

Stipules thin and scarious, lanceolate, deciduous. Autumn leaves russet brown or fawn: young leaves olive and russet browns.

Venation strict-pinnate; the midrib strong to the middle, the secondaries sharp, alternate, running straight to the margins and ending there, but the lower in divergent lines and may tend to loop slightly and their attenuated

ends to branch close within the margin. Angles about 35—45°. Tertiaries not looped beneath the slightly undulating margin. Each pair of secondaries distant about $\frac{1}{8}$ of the length of the midrib, the lowest much shorter than those in the middle of the leaf, and devoid of prominent outer veins, and curved outwards. Secondary segments narrow, the middle nearly linear. Tertiaries at rather acute angles from outside the secondaries, at right angles or slightly obtuse inside: the axial ones chiefly slightly acute, all connecting. Network well developed: meshes rather loose and rounded.

(ii) Leaves spiral on all the shoots.

[For (β) see p. 294.]

(*a*) *Leaves stipulate.*

[See note, p. 161.]

* Leaves lanceolate or very narrow-lanceolate. Silky or tomentose beneath.

† Leaves linear-lanceolate, with waved edges; about 10—30 × 0·5—2 cm.

Salix viminalis, L. Osier (Fig. 109). An osier shrub with silky shoots and buds, and very narrow and long waved leaves. Leaves herbaceous, lanceolate to linear-lanceolate, acuminate, 10—18 cm. × 5—12 mm., but up to 20—30 cm. long, usually about 8—10 times as long as broad, and pointed both ends: petiole 5—12 mm., dilated below, or sub-sessile. Entire or obscurely toothed at the wavy margins, which may be also revolute, especially in youth. Upper surface green or greyish green and more or less shining glabrous or pulverulent, and reticulate; densely silvery silky or grey-tomentose beneath, the hairs parallel to the secondaries. Midrib often orange or fawn-coloured, and the venation prominent but not strong. Stipules linear-lanceolate to subulate, or on the strong

shoots broader and glandular-toothed, caducous. No upper stomata. Autumn leaves yellow.

Fig. 109. Osier, *Salix viminalis*, p. 286 (Sc).

Venation weak, pinnate-reticulate, though the curved secondaries breaking up soon after leaving the midrib may be fairly distinct. Tertiaries weak and numerous, and

tend to form cross-ties, coming off at open angles. The secondaries are very short, and leave the midrib at open or nearly right angles.

[There are several varieties, but the very narrow wavy leaves, silky beneath, characterise the species. The silky appressed hairs parallel to the secondaries, not to the midrib, distinguish it from *S. alba*: see p. 244.]

†† Leaves not more than 1—6 × 1—1·5 cm.

Salix repens. The leaves may be entire, and may then be classified here (see p. 243), and similarly with the rare *S. Lapponum* (see below). *S. nigricans* has also occasionally narrow and entire stipulate leaves (see p. 292).

** Leaves broader, elliptic to ovate, obovate, &c.

† Leaves hoary or tomentose, and white or grey beneath. Rare dwarf or alpine prostrate shrubs, with prominent and reticulate venation beneath.

⊙ *Leaves rugose.*

Salix Lapponum, L. Downy Willow. Rare sub-alpine creeper, with very variable elliptic, ovate, or oblong-elliptic or obovate-lanceolate, to lanceolate leaves equally attenuated at base and apex, tomentose below, and often above also; acute or acuminate, the margins nearly parallel in the middle, entire or faintly undulate-dentate, rugose; silky velvety or arachnoid when young, at length white cottony beneath and dull or almost bright green or silky villous above, 3·5—7 × 1—2 cm. (3—9 × 0·8—3·5 cm.); petiole up to 1 cm. Stipules small or obsolete. No stomata on the upper surface. Venation pinnate-reticulate, rather prominent beneath. Autumn leaves yellow.

[Forms of *Salix repens* with small broad entire leaves may also come here. See p. 243.

Salix Caprea, *S. aurita* and the var. *S. cinerea* sometimes have the leaves entire, and may then be placed here. See pp. 255, 257.]

⊙⊙ *Leaves not remarkably rugose.*

□ *Leaves glabrous above.*

Cotoneaster vulgaris, Lindl. Cotoneaster (Fig. 110). Rare dwarf shrub, with red-brown twigs pubescent at the tips. Leaves sub-sessile, 2—5 cm. long (2—6 cm. × 12—30 mm.), leathery, ovate, broadly elliptic-oblong or sub-orbicular; obtuse, acute, or even slightly retuse or mucronate, entire, green and nearly glabrous above, grey-tomentose or densely pubescent beneath. Stipules minute, scarious, deciduous; petiole very short, 2—5 mm., tomentose. Autumn leaves brown.

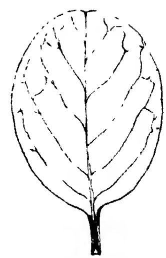

Fig. 110. Cotoneaster, *Cotoneaster vulgaris*, p. 289 (D).

Venation reticulate. The weak secondaries start at about equal angles and as if pinnate, but soon break up, and loop within the margin, without distinct secondary or superposed loops: loops strongly convex to the margin, but may run near it and almost form an infra-marginal vein. Meshwork abundant. The secondaries in mid-leaf about $\frac{1}{4}$ the length of the midrib apart, more evidently or much branched.

□□ *Leaves silky above, with a golden shimmer.*

Salix lanata. Woolly Willow. Very rare dwarf alpine creeper. Leaves broad obovate to ovate, to more or less cordate; or oblong-lanceolate, about 3 × 1·6 cm. (3—10

cm.); acute, densely woolly or silky tomentose on both surfaces, entire, reticulation prominent beneath, sub-coriaceous, petioles short; stipules half-cordate, glandular-serratulate or entire. No stomata on the upper surface. Closely allied to *S. Lapponum*. Autumn leaves yellow.

†† Leaves glabrous or glabrescent, not tomentose beneath.

☉ *Petioles relatively long. Reticulation distinct.*

□ *Leaves 3—5 cm., broadly oval to sub-rotund. Tree with thorny dwarf shoots.*

The Pear occasionally has entire leaves, and may be looked for here. See p. 274.

[The same is true of the occasionally entire cordate leaves of *Populus tremula*. See p. 264.]

□□ *Leaves not larger than 2—4 cm. or so, obovate to sub-orbicular. Dwarf creeper with no trace of thorns.*

Salix reticulata. Reticulate Willow (Fig. 111). Small, rare Northern creeper with twigs 5—20 cm. long. Buds few, 2—4, aggregated at the tips of the shoots. Leaves 12—16 mm. diam. up to 2—3 cm. (1—4 × 0·8—2·5 cm.), oblong-orbicular or elliptic-rounded, obovate to obcuneate, sub-rotund, or orbicular; firm, obtuse or slightly retuse: margins entire or waved, or slightly reflexed, dark green, somewhat shiny, and rugose above, glabrous, glaucous, bluish grey or white and hoary glaucous beneath; with very prominent reticulation on both surfaces. Young

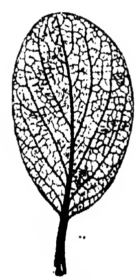

Fig. 111. **Reticulate Willow,** ***Salix reticulata*****, p. 290 (Ett).**

leaves silky. Petiole long and slender, reddish, channelled, pubescent at the base. Stipules obsolete. No stomata on the upper surface. Autumn leaves yellow.

Venation pinnate-reticulate, the secondaries running towards, but not reaching the entire margin; rapidly curving, looping, and breaking into a close meshwork of tertiaries, which often leave the outer side at acute, the inner side at open angles, and form distinct cross-ties. Secondaries leave the midrib at very acute angles, few, 2—4 each side, strong, approximated towards the base of the leaf, and tending to converge towards the apex, as in pinnate-arcuate venation. Tertiaries also strong and reticulation therefore very prominent below.

⊙ ⊙ *Petiole relatively short; leaf not prominently reticulate.*

□ *Venation pinnate-arcuate.*

•

Rhamnus Frangula, L. Alder Buckthorn (Fig. 112). Shrub with dark foliage, and yellow malodorous cortex, bitter, and staining the saliva yellow. Leaf broadly elliptic or ovate to obovate or oblong, obtuse or acuminate, 4—7 × 2—5 cm.; entire or very slightly undulate, glabrous or with faint pubescence on the veins or in their angles beneath. Thin, green and rather matt above, paler and brighter beneath. Venation not prominent. Petiole short (5—10 mm.), stipules minute, subulate, caducous. Autumn leaves reddish and green.

Venation pinnate-arcuate and looped. The midrib gives off about 8 strong secondaries rather close together on either side in pinnate fashion. These start nearly straight, but curve strongly forwards beneath the margin, and tend to form slight and inconspicuous loops close beneath it, and then break into the network. Secondaries

fairly equidistant all the way up the midrib, and not converging at the apex.

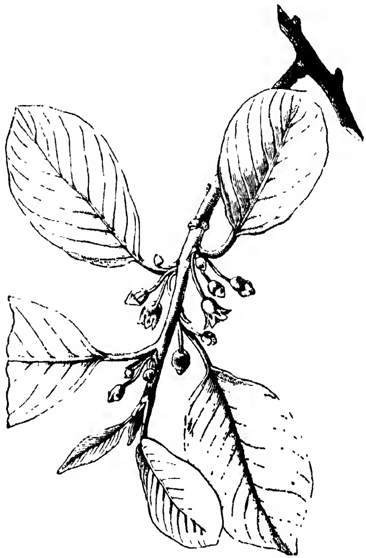

Fig. 112. Buckthorn, *Rhamnus Frangula*, p. 291 (Wo).

□□ *Venation not arcuate. Leaf elliptic- to ovate-lanceolate,* 3—10 *cm. long, glabrescent or glaucous beneath.*

§ *Dull deep green above, black on drying: stipules broad and toothed.*

Salix nigricans, Sm. Black Willow. Shrub, very variable, closely allied to and perhaps only a form of *S. phylicifolia.* Leaf thin, 3—10 × 1·2—4·5 cm., generally elliptic, ovate-oblong, cordate or lanceolate; but may be elliptic-lanceolate, ovate or obovate, and 2—3 times as long as broad; acute or shortly acuminate; attenuate, rounded or cordate

below. Undulate dentate, or crenate-serratulate with rather coarse rounded teeth, or entire. Deep green and reticulate above, hardly shiny, pubescent when young, becoming glabrous above; usually glabrescent beneath, with a few hairs on the venation, or bluish-glaucous and paler, with greener margins and apex. Blackening when dried. Petiole up to 2 cm. long, more or less velvety-pubescent. Stipules obsolete or broad and toothed, half-cordate. There are no stomata on the upper surface. Autumn leaves yellow.

Venation pinnate-reticulate, the 6—12 distinct curving secondaries lost in the meshwork before reaching the serrate margin, and often looping just beneath it. Long axes of the meshes oblique. Tertiaries numerous, leaving the outer sides of the secondaries at acute angles, the inner at obtuse angles, and forming cross-ties: secondaries leaving the midrib at open angles, rather distant, long, strong, those in the middle of the leaf but little weaker than the midrib above. Tertiaries also somewhat strong, and venation therefore prominent below.

[The leaves of the Pear (p. 274) and of *Salix purpurea* (p. 178) also blacken on drying.]

§§ *Shining green above, not black on drying: stipules small or obsolete.*

S. phylicifolia, L. Tea-leaved Willow. Small shrub, very variable, the downy young shoots and usually distant leaves becoming glabrous. Leaf 3—6 cm. (2—9 × 0·6—4·5 cm.), ovate, elliptic or oblong-ovate to obovate, obovate-lanceolate, or lanceolate, cuneiform at the base, 2—3 times long as broad; acute or acuminate or even gutter-pointed, entire or feebly distant toothed or crenate-serrate or entire. At first slightly pubescent, then glabrous, firm, deep shining green, furrowed but not wrinkled, and shining

above; with rather prominent venation, bluish-glaucous, but not silky, beneath, with the principal veins yellowish and hardly prominent. Stipules obsolete or very small, lanceolate, erect. Not black when dry. Petioles very short, about 1 cm., villous. There are no upper stomata. Autumn leaves yellow. Venation as in *S. nigricans*.

[*S. nigricans* and *S. phylicifolia* offer peculiar difficulties, owing to their great variability. As a rule the more equal size, thinner texture, more reticulate and duller upper surface, the more glaucous under surface, the blackening on drying, and the broader toothed stipules, as also more pubescent shoots and twigs, distinguish the former. Both offer difficulties of transitional characters towards *S. Myrsinites* and *S. Caprea* and their allies.]

(β) *Leaves exstipulate.*

[For ** see p. 299.]

* Shoots or leaves, or both, spinescent or thorny.

† Shoots leafy or leaf-like; some or all of them converted into thorns or spines.

(•) *Leaves deciduous, oblong-lanceolate to linear-lanceolate, silvery scaly or bronzed beneath; shoots thorny and covered with waxy bloom or with bronze scales.*

Hippophaë rhamnoides, L. Sea Buckthorn (Figs. 113 and 114). Much branched thorny shrub, with bronzed or silvery shoots and leaves. Leaves 1—6 cm. (4—5 cm. × 5—6 mm.), sub-sessile, obovate, narrow oblong-lanceolate to linear-oblong, or even linear; obtuse, sub-coriaceous, deep green and nearly glabrous or white dotted with scattered stellate hairs, silvery grey with scaly scurf beneath, the midrib with rusty scales. Thorns axillary or terminating the shoots. Petiole 1—3 mm., with rusty

bronze scales as on the shoots. Autumn leaves yellow. Venation obscurely pinnate.

Fig. 113. Sea Buckthorn, *Hippophaë rhamnoides*, p. 294 (Sc).

[The only other shrub with silvery and bronze scales, likely to be met with in gardens, is *Eleagnus*.]

⊙ ⊙ *Leaves and shoots devoid of waxy bloom or silvery and bronzed scales.*

☐ *Leaves foliaceous, thin, deciduous, more or less lanceolate; not themselves pungent or spinose.*

§ *Leaves lanceolate, 5—10 cm. long: shoots slender and arching.*

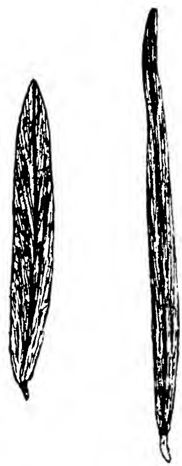

Fig. 114. Sea Buckthorn, *Hippophaë rhamnoides*, p. 294 (D).

Lycium barbarum, L. Tea Tree. Hedge bush, with long thin arched shoots. Leaves lanceolate or elliptic-lanceolate to narrow-lanceolate or rhomboid-ovate, herbaceous, soft and thin, attenuate both ends, sub-sessile, entire, green, 5—11 × 1—4 cm., with axillary slender branch thorns, or in some cases thornless. See p. 303. Petioles 5—10 mm. Autumn leaves yellow.

Venation obscurely pinnate-reticulate, the secondaries fairly strong, leaving the midrib at open angles of about 60°, and soon looping forwards irregularly. Tertiaries few. Meshes sparse and open.

§§ *Leaves minute, 5—8 mm. long, narrow-lanceolate or obovate: shoots erect.*

Genista anglica, L. Petty Whin. Small spinescent bush, with simple slender recurved spines, in the axils of minute sub-sessile leaves. Leaves small, 4—8 × 1—3 mm., often crowded in tufts, dark green, glabrous; on the flowering shoots slightly ovate, oblong-ovate or obovate, acute or obtuse; those on the sterile shoots narrow-lanceolate, acute. Spines simple, slender, spreading or recurved, 2—3 cm. Stipules obsolete. Venation obscurely pinnate. Autumn leaves yellow.

[Although belonging to a group, Leguminosæ, typically stipulate and with compound leaves, *Genista anglica* has no stipules and the leaves are reduced.

The spinescent shoots of *Ulex* occasionally bear a few minute unifoliolate leaves.]

▱ ▱ *Leaf-like shoots (cladodes) ovate-lanceolate, stiff, spine-pointed, and evergreen.*

Ruscus aculeatus. Butcher's Broom. Small evergreen bush, with crowded, hard, stiff, prickle-pointed, leaf-like branches (cladodes), on the flat surfaces of which the flowers are borne in the axils of minute scarious scales. Long shoots cylindric, hard, dark greyish green, grooved and ridged, the ridges puberulent; springing from the axils of flattened brown scales, with thin linear insertions extending about $\frac{1}{3}$ of the way round the shoot. Cladodes 2—5 cm. (2—3 cm. × 8—12 mm.), ovate-lanceolate to elliptic-ovate, acuminate, pungent, hard, rigid, entire, twisted on the narrow sub-sessile bases; dark green, glabrous and shining on both surfaces, each subtended by a minute subulate scarious scale (the true leaf).

Venation of three principal veins, slightly prominent

below, the central simulating a midrib, the two laterals arching from below and converging towards the apex. Brown when dying.

†† Plant apparently leafless, both leaves and shoots being converted into sharp spines and thorns. Evergreen, pubescent.

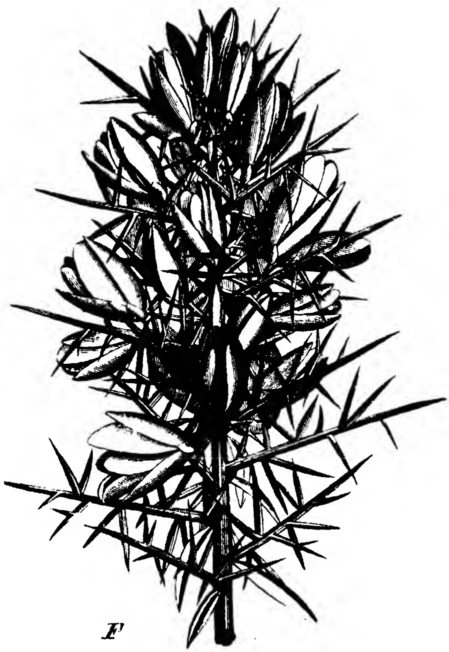

Fig. 115. Gorse, *Ulex europæus*, p. 298 (E & P).

Ulex europæus, L. Gorse (Fig. 115). Small densely spiny bush. Leaves reduced to scales, 5—10 mm. long, or converted into sharp subulate persistent spines, bearing

branched thorns in their axils, all greyish green, pubescent, and very sharp and rigid. Spines 3—6 cm. long.

Ulex nanus, L., the Dwarf Furze, is smaller, with more slender and crowded thorns, about 1—3 cm.

[It should be noted that the above only applies to grown-up plants: the seedlings have true compound trifoliolate, hairy and stipulate leaves, proper to the group of Leguminosæ to which the genus *Ulex* belongs. See p. 161. Sometimes the spines (branches) of older plants bear a few minute unifoliolate leaves.]

** Shoots entirely devoid of spines or thorns.

[The narrow leaves of the conifers may be somewhat sharp-pointed (pungent), but they are not converted into true spines. See pp. 316—318.]

† Leaves foliaceous and of appreciable breadth, neither scale-like nor acicular, linear, &c. [For †† see p. 305.]

⊙ *Shoots and leaves glandular hairy, aromatic when bruised, the latter cuneate-oblong and serratulate at the tips, or lanceolate.*

Myrica Gale often has its cuneate-oblong or lanceolate leaves entire, and may then be sought for here. See p. 283.

⊙ ⊙ *Neither glandular hairy nor aromatic.*

□ *Leaves highly polished, or shining above, hard or tough evergreen.*

§ *Leaves at least 3—15 cm. long; more or less oblong-lanceolate, and in tufts at the end of the shoots; edges not revolute.*

‡ *Shoots remarkably supple and tough.*

Daphne Laureola, L. Spurge Laurel (Fig. 116). Small under-shrub with remarkably pliant and tough stems.

Leaves 3—15 cm. (5—8 × 2—3 cm.), coriaceous, evergreen, cuneate-lanceolate or oblong or obovate-lanceolate, acute, attenuated at base and sub-sessile; glabrous and very

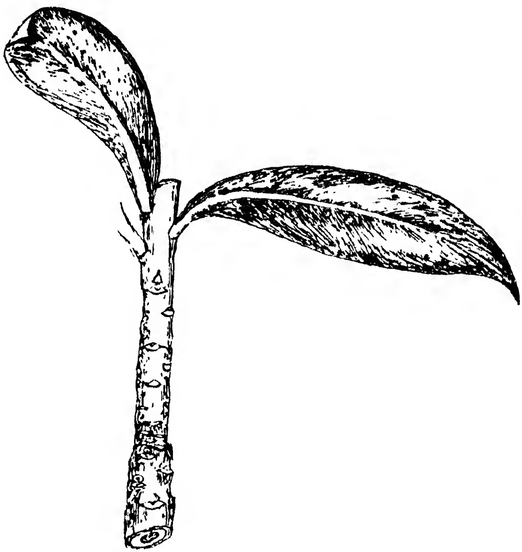

Fig. 116. Spurge Laurel, *Daphne Laureola*, p. 299 (D).

polished dark green above, paler matt green below. The leaves in crowded rosettes towards the ends of the shoots. Venation obscure. Dying leaves brown.

‡‡ *Shoots rigid and brittle.*

÷ *Leaves more than 5 cm. long; not glaucous or revolute.*

Rhododendron ponticum, L. Rose Bay. Evergreen shrub. Leaves large, oblong-lanceolate, coriaceous, attenuated below; deep polished green above, paler or more

or less ferruginous beneath. Petiole short and thick. Venation pinnate. Dying leaves yellow.

÷ ÷ *Leaves not more than* 30 *mm. long, strongly revolute and very glaucous beneath.*

Andromeda polifolia, L. Marsh Andromeda. Leaves very small, evergreen, 15—30 × 3—7 mm., oblong-lanceolate to linear-lanceolate; alternate, strongly revolute, entire, acute, sub-sessile. Leathery, stiff; shining dark green above and very glaucous beneath, with a yellow midrib.

[The rare evergreen species *Menziesia polifolia*, St Dabeoc's Heath, with more or less ovate leaves, revolute at the margins and white-tomentose beneath, and the still rarer *M. cærulea* with linear, minutely serrulate leaves, green on both sides, may be mentioned here.]

§§ *Leaves small and Box-like, not more than about* 30 *mm. long; more or less ovate to obovate; not in tufts; margins revolute.*

‡ *Leaves* 15—30 *mm. long, punctate with minute brown depressed dots beneath; margins often minutely and faintly crenate-serratulate.*

Vaccinium Vitis-idæa, L. Cowberry, Red Whortleberry. Leaves hard, coriaceous, glabrous, shining green above, and resembling those of the Box, but alternate; evergreen, obovate, elliptical, or oblong, paler and punctate with brown dots beneath; apex obtuse or faintly retuse and with a thick glandular mucronate point, margins revolute and entire or faintly crenate-serrate; shortly petiolate (1—2 mm.); 15—30 × 1—2 mm. Autumn leaves red.

‡‡ *Leaves not more than* 15 *mm. long; not punctate beneath; quite entire.*

÷ *Leaf very glaucous beneath; about* 7—9 *mm. long; margins strongly revolute. Shoots very thin and wiry.*

Vaccinium Oxycoccus, L. Cranberry. Leaves alternate, evergreen, coriaceous, small, sub-sessile, more or less pseudo-distichous on very wiry shoots; ovate or oblong-ovate to nearly lanceolate, acute, entire and strongly revolute, 7—9 × 3—5 mm.; glabrous, polished dark green above, very glaucous beneath. Autumn leaves red.

÷ ÷ *Leaf about* 12—15 *mm. long; not glaucous or strongly revolute. Shoots stouter.*

Arctostaphyllos Uva-ursi, Spreng. Bearberry. Leaves glabrous, evergreen, rigid and coriaceous, sub-sessile or narrowed to a short petiole, obovate or oblong, obtuse, quite entire, and not revolute, but ciliate; resembling those of the Box, but alternate; shining green, paler beneath; about 12—15 × 5—10 mm. Venation reticulate, very distinct. Autumn leaves bright reds to purplish browns.

[The much rarer *A. alpina*, with narrower, thinner, veined leaves, not evergreen but withering in autumn, may be mentioned.]

□ □ *Leaves neither highly polished nor evergreen, but thin and deciduous.*

§ *Leaves more or less lanceolate.*

‡ *Leaves in rosettes on stiff or supple erect branches.*

÷ *Leaves glabrous.*

Daphne Mezereum, L. Mezereon (Fig. 117). Small shrub flowering before the tufted foliage appears. Leaves 7—9 × 3—5 (6—10) cm., thin, soft, smooth, deciduous, narrow-oblong, oblong- or obovate-lanceolate or cuneate-lanceolate, acute, attenuate to sub-sessile at the base; glabrous, glaucous or pale green above, bluish beneath, in rosettes at the ends of the long shoots. Autumn leaves yellow.

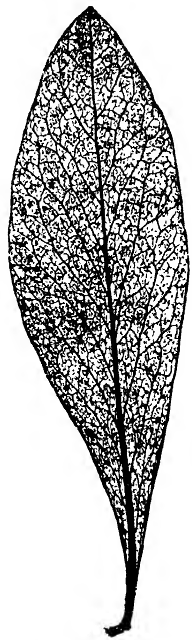

Fig. 117. Mezereon, *Daphne Mezereum*, p. 303 (Ett).

Venation pinnate-reticulate, the secondary veins running from the midrib towards the margin, but soon curving and breaking into a network of tertiaries, the meshes of which are large and have their long-axes oblique to the midrib. Tertiaries numerous, leaving the secondaries at various angles.

÷ ÷ *Leaves pilose and ciliate.*

Azalea pontica, L. Azalea. Small shrub, with deciduous clammy leaves. Leaves ovate-oblong or -lanceolate, pilose and ciliate.

‡‡ *Shoots arched and slender, but not climbing: leaves lanceolate.*

Lycium barbarum, when, as often occurs, the lanceolate

leaves are unaccompanied by spines, comes here. See p. 296.

§§ *Leaves more or less ovate, to sub-orbicular.*

‡ *Leaves 5—10 cm. long, not glaucous beneath. Bush with climbing or twining scrambling shoots.*

Solanum Dulcamara, L. Bittersweet. Bush, partly climbing, with bitter cortex and sweet wood; the leaves variable, 5—10 cm. long (4—12 × 1·5—5), usually entire, ovate or ovate-lanceolate, acute or acuminate, but may have two prominent auriculate and asymmetrical lobes at the base on the upper leaves, making them 3-lobed and hastate or even 3-partite, like auricles or pinnules, or an odd lobe may occur. Glabrous or pubescent with appressed hairs, often purplish above. Base usually broadly cordate, or decurrent on to the petiole which is half-terete grooved above, about 1—3 cm. Autumn leaves brown.

Venation pinnate-reticulate.

‡‡ *Leaves not more than about 25 mm. long, glaucous beneath. Small spreading under-bush.*

Vaccinium uliginosum, L. Bog Whortleberry. Leaves alternate, on terete shoots; obovate to elliptical or sub-orbicular, thin, glabrous, deciduous, quite entire, with distinct reticulate venation; obtuse or slightly emarginate above; bright matt green above, glaucous beneath. Shortly petiolate; about 15—25 × 10—20 mm. Autumn leaves red.

[Forms of *Salix nigricans* (p. 292), *S. phylicifolia* (p. 293), *S. repens* (p. 243), as well as the rare alpine creepers *S. Lapponum* (p. 288) and *S. reticulata* (p. 290), may occur with the stipules obsolete, and the leaves broad, and may then be sought for in this section.]

†† Leaves scaly or very narrow, acicular, linear, &c.

⊙ *Leaves small, 2—5 mm. long, green, scale-like, and closely imbricated on the slender shoots.*

Tamarix Gallica, L. Tamarisk. Small tree with slender branches, and somewhat Cypress-like or Willow-like habit. Leaves ovate or ovate-lanceolate, about 5 mm. long, minute, triangular, auriculate, or broadly sessile and keeled; or subulate and densely imbricate. Rather glaucous, dotted, long-acuminate, white and membranous at the margins. Autumn leaves brown. Venation simple.

[The only similarly shaped and crowded leaves (Ericoid) are found in Cypress, *Thuja*, the Ling, and Heaths; all easily distinguished. See pp. 191—193.]

⊙ ⊙ *Green foliage-leaves very narrow and stiff —linear, acicular, &c.—often accompanied by very small and scale-like, brown leaves elsewhere on the shoots. Plants not armed with thorns or prickles, though the leaves themselves may be hard-pointed and pungent. Dying leaves yellow. Venation simple.*

□ *Acicular leaves (needles) in fascicles of 25—50 or more on the dwarf shoots; surrounded below with scarious scale-leaves, and springing from the axils of similar scales on the long shoots. The latter also bear scattered green leaves here and there. Shoots resinous.* [For □ □ see p. 313.

§ *Fascicles of needles stout and tubercular, containing 25—50 or more foliage-leaves, each 2—4 cm. long.*

♯ *Leaves deciduous and bright green, soft, 30—40 or more in the tuft.*

Larix europæa, L. Larch (Fig. 118). Large tree with slender and long drooping branches, bearing light foliage in distant tufts. Leaves 2—3 cm. long (1—3 cm. × 0·5—

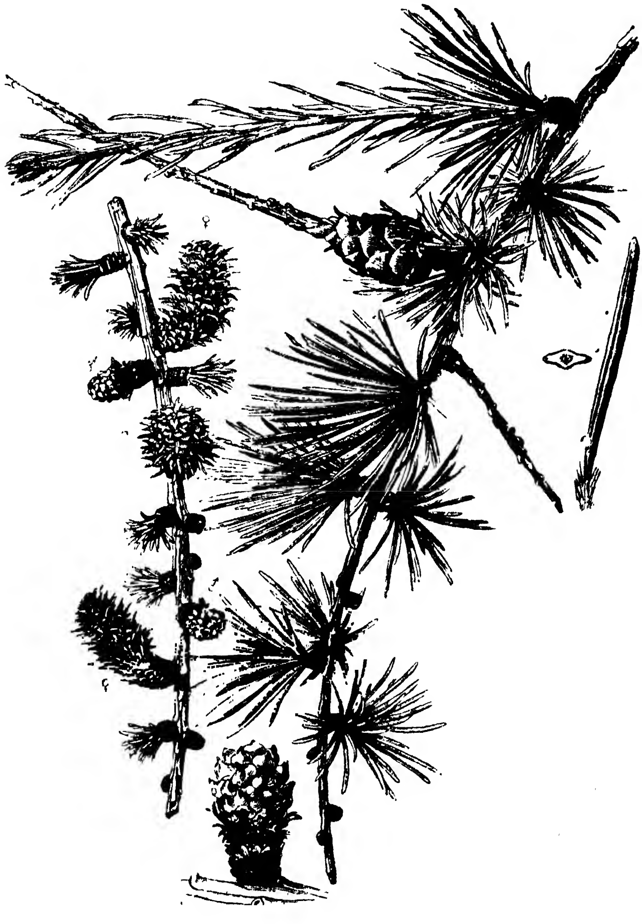

Fig. 118. Larch, *Larix europæa*, p. 306 (Wi).

0·75 mm.); soft, bright green, solitary and spiral on the long shoots, closely fascicled and of unequal lengths on the tuberculate dwarf shoots; the tufts distant. Narrow-linear, obtuse, obscurely keeled above, strongly beneath. Venation simple. Two resin-canals: one at each angle of the leaf. Vascular bundle single. Dying leaves yellow.

[The Larch is the only European Conifer with deciduous leaves.]

‡‡ *Leaves dark green and rigid, evergreen.*

Cedrus Libani, Loud. Cedar of Lebanon. Large spreading tree, with dark evergreen terraced foliage. Leaves coriaceous and rigid, acicular, somewhat tetragonal, pungent, scattered spirally on short pulvini on the long shoots, and 20—40 mm. long; in fascicles of 25—50 or more on the tuberculate dwarf shoots, and 12—15 mm. long; dark green and evergreen, persisting 3—4 or 5 years. Dying leaves brown. Stomata on the lower surface. Venation simple. Vascular bundle undivided.

[*Cedrus Deodara*, Loud., the Deodar of the Himalayas, and *C. Atlantica* (Manetti), the Atlas Cedar of N. Africa, are geographical races of the same species, differing in habit, length of leaves, size of cones, &c.

Generally speaking, these characters may be summed up as follows, but they graduate considerably as the trees advance in age.

In *Cedrus Libani*, the habit is more tabular and terraced, the leaves of medium length, and the cones about 10—15 cm. long.

In *C. Atlantica*, the habit is more rigid and less tabular, the leaves shorter and stiffer and more silvery glaucous, and the cones smaller. Stomata chiefly on the upper surface, according to Masters.

In *C. Deodara*, the habit is more slender and pyramidal, with pendulous leaders and upper shoots, the leaves longer, bluntly triangular or rounded, and of a brighter green, and the cones longer.]

§§ *Fascicles of needles slender, and containing not more than* 2—5 *acicular leaves; shoots resinous. Evergreen. Mesophyll-cells with involute foldings of the walls: endodermis well defined.*

♯ *Needles* 5 *in each fascicle: trigonal in section, rounded beneath.*

÷ *Needles short and rigid,* 6—12 *up to* 10—15 *cm. long: scales of the fascicle (dwarf shoot) caducous. Cones erect, ovoid, obtuse,* 7—10 *cm. long.*

Pinus Cembra, L. Arolla Pine. Alpine Pine with irregular form. Leaves rigid, strong, erect or hardly spreading, 5—8 cm., 6—12 cm. or up to 10—15 cm. long, hardly pointed, glaucous and keeled above with white stomatal lines; green and rounded beneath: edges harsh with minute serratulæ towards the tip, and somewhat broader below. Sheath short or long and caducous, reddish. Leaves persisting 4—5 years. Dying leaves yellow. Shoots pubescent. Cones ovoid, 7—10 cm., obtuse. Resin-canals 3, all round the leaf. Venation simple. Vascular bundle single.

÷÷ *Needles long and slender,* 10—20 *cm. or more. Cones pendent, cylindric-tapering,* 15—25 *cm. long.*

Pinus Strobus, L. Weymouth Pine. Tall tree. Leaves slender, triquetal, 10 or 12 (6—12) cm. long; acute, bluish

green in the mass, the convex side green, the flat sides with silvery stomatal lines, margins serratulate; basal sheath short and deciduous, orange-reddish. Leaves persisting 2—3 years, the tufts collected towards the apex of the shoot. Dying leaves yellow. Cones terete-obtuse, curved, 15—18 cm. long. Resin-canals all round the leaf, encircled by thin-walled cells. Venation simple. Vascular bundle undivided.

[It is almost, if not quite, impossible to distinguish this by the leaves only from the following similar Pines.

Pinus monticola, Don. Tall tree, much like *P. Strobus.* Leaves clustered towards the tips of the shoots, slender, 12—15 cm. long, trigonal, margins hardly serratulate; 3—5 white stomatal lines on the upper flat sides, bright green beneath. Basal sheath pale brown, deciduous, about 2 cm. long. Dying leaves brown.

Venation simple. Resin-canals encircled by thin-walled cells. Vascular bundle single.

Twigs red-brown, scarred with leaf-bases. Cone terete-pointed, curved, 20—25 cm. long.

Pinus excelsa, Wall. Himalayan Pine. Tall tree. Leaves filiform, 10—15 or up to 20 or more cm. long, triquetal, bright green beneath, silvery or greyish on the flattened upper sides, margins minutely serratulate; basal sheath 2 cm. long, pale brown, deciduous. Leaves persistent 3—4 years. Dying leaves yellow. Shoots olive. Cones 18—25 cm., terete-pointed. Venation simple. Resin-canals encircled by thin-walled cells.]

♯♯ *Needles not more than 3 in each fascicle.*

÷ *Needles 3 in each fascicle, trigonal.*

Pinus Tæda, L. Torch Pine. A North American Pine with very bright green foliage. Leaf trigonal in section, mucronate, minutely serratulate, 10—15 (16—20) cm. long, persisting 2—3 years. Grass-green beneath, and with 8—10 or more white stomatal lines on the flat faces. Dying leaves yellow. Basal sheath about 3 cm., usually torn. Resin-canals in centre of mesophyll.

Venation simple. Vascular bundle double.

÷ ÷ *Needles 2 in each fascicle, semi-terete, the flattened faces opposed. Sheath persistent.*

8 *Needles short, about 5—7 cm.*

Pinus sylvestris, L. Scots Pine (Fig. 119). Tree with orange or sienna-coloured bark. Leaf 4—7 (rarely up to 10) cm., persisting 3—4 years; rigid, straight, or curved and twisted, slightly spreading, bluish or glaucous when young, then dark green on the convex, and glaucous on the plane side. Slightly rough at the angles; apex callous, acute or even pungent. Sheath of fascicle wrinkled and blackish, 1 cm. long, of numerous minute scales, persistent; the remains of similar scale-leaves along the older twigs. Very resinous. Resin-canals numerous, all round the leaf, each encircled by sclerenchyma.

Venation simple. Vascular bundle double. Dying leaves yellow.

[There are numerous varieties, differing in habit, colour, length of leaves and cones, &c.

Allied to this is *P. montana*, the Mountain Pine, a more or less prostrate alpine species with thick and rigid needles, 2—5 up to 6—8 cm. long, deep green both sides, often falcate, blunt, in crowded tufts and persisting 4—5 years.]

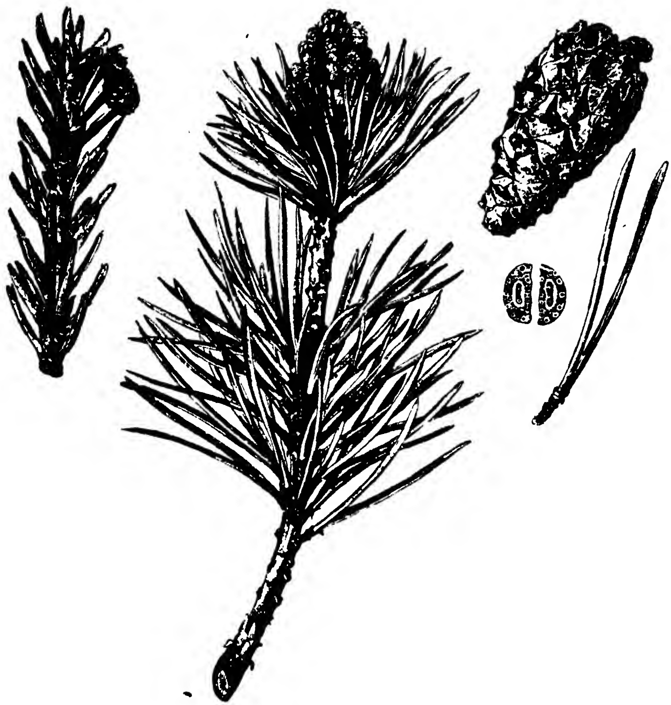

Fig. 119. Scots Pine, *Pinus sylvestris*, p. 310 (Wi).

8 8 *Needles longer, at least* 8—15 *and up to* 30 *cm. long.*

Δ *Leaves* 10—15 *cm., or up to* 18 *cm.*

P. Laricio, Poir, var. *Austriaca.* Black Pine, Austrian Pine (Fig. 120). Tall tree with very dark bark and foliage. Leaves rigid or sinuous, deep green on both faces, 8—18 cm. long; stout, slightly obtuse or acute, hardly pungent,

tip yellowish and hard, semi-terete or slightly channelled above, margins minutely serratulate, persisting 3—4 or even 6 years. Dying leaves yellow. Basal sheath 1·5 cm., whitish or yellowish, becoming shorter and darker. Resin-

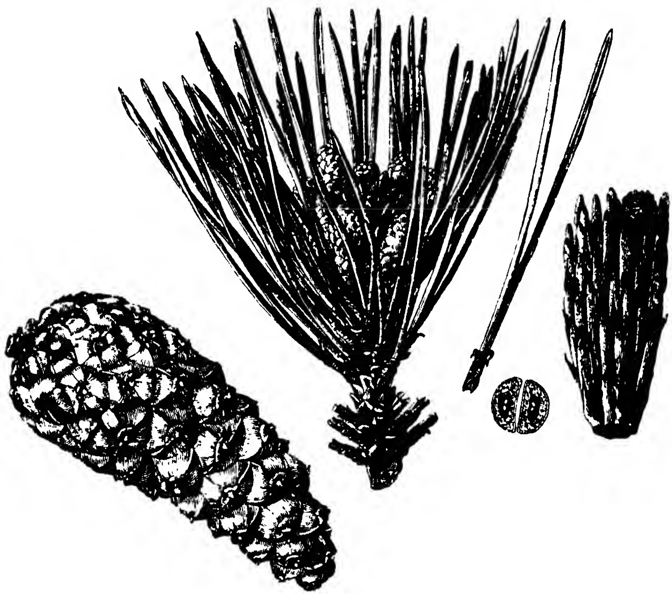

Fig. 120. Austrian Pine, *Pinus Laricio*, var. *Austriaca*, p. 311 (Wi).

canals numerous, all round the leaf, each encircled by sclerenchyma. Venation simple. Vascular bundle double.

[Other allied varieties are *P. pyrenaica* and *P. corsica.*]

ΔΔ *Leaves at least* 15—30 *cm. long*

σ *Leaves* 15—20 *cm. long.*

Pinus Pinea, L. Stone Pine. Large tree, umbrella-shaped when old. Leaves extended, 15—18 cm. (8—

20 cm. × 1·5—2 mm.), rather slender, bright green, loose on the branches. Margins scabridulous, straight or twisted: tip pungent, yellowish. Basal sheath grey, becoming darker and torn. Resin-canals all round the leaf, each encircled by sclerenchyma. Venation simple. Dying leaves yellow.

ƍƍ Needles about 20—30 *cm. long.*

Pinus Pinaster, Soland. Cluster Pine. Large tree of sandy coasts, &c. Leaves 18—30 cm. (8—30 cm. × 2 mm.), thick and fleshy, fresh green both sides, slightly shining, rigid, often twisted, mostly clustered towards the ends of the shoots. Margins slightly serrulate, sub-acute and pungent. Basal sheath 1—2 cm., whitish, wrinkled, becoming blackish. Resin-canals in the centre of the mesophyll. Venation simple. Vascular bundle double. Dying leaves yellow.

□□ Leaves not in fascicles, but isolated and spiral on the shoots, evergreen.

§ Leaves linear, more or less flat, and so twisted as to lie in one plane, right and left of the shoot, as if combed out horizontally—pseudo-distichous.

[This pseudo-distichous arrangement must be carefully distinguished from true distichy. In the latter case the leaf-insertions are themselves right and left on the shoot: in the former the leaf-insertions are spiral and the leaves twisted into the right and left positions. See p. 11.]

♯ Lower side of the leaf with two longitudinal silvery white lines of stomata: leaf obtuse or notched at the apex. Endodermis well defined. Leaf-base not prominent. Shoots resinous.

Abies pectinata, D.C. Silver Fir (Fig. 121). Tall Fir, tapering, with branches in pseudo-whorls, the leaves on the leader radiating in spirals, becoming looser downwards,

Fig. 121. Silver Fir, *Abies pectinata*, p. 314 (Wi).

and the twigs markedly pseudo-distichous, and bearing horizontally displayed shoots of densely spiral leaves. Leaves 2—4 cm. long (12—28 × 3 mm.), persisting 5—7 or even 8—11 years, solitary, those on the upper and lower sides of shoot twisted at the base into two or three pseudo-distichous ranks in the horizontal plane; flat, linear, obtuse

or emarginate: dark polished green above, and grooved along the midrib, paler and with two silvery stomatal lines beneath. Dying leaves yellow. On the cone-bearing shoots the leaves are more upturned. Petiole short, leaving a smooth circular scar. Stomata beneath only: palisade layer present. Venation simple. Vascular bundle double. A resin-canal in each angle.

Lower surface of leaf glaucous, but devoid of the silvery stomatal lines; apex acute but not pungent. Shoots not resinous.

Taxus baccata, L. Yew (Fig. 122). Dark bushy tree.

Fig. 122. Yew, *Taxus baccata*, p. 315 (Wi).

Leaves flat, linear or linear-falcate, solitary and scattered, persisting 3—4 years, the upper and lower on lateral branches twisted into the horizontal plane; dark shining green above, pale beneath with prominent midrib, acute, 2—4 cm. × 1—2 mm. Petiole rather well marked. Dying leaves yellow. Stomata on the lower surface. Venation simple. Vascular bundle undivided.

§§ *Leaves more acicular, and hardly or not at all twisted into the pseudo-distichous position. Shoots resinous.*

‡ *Leaves quadrangular in section, and almost equally disposed round the shoots, acute and pungent. Endodermis well defined. Leaf-base prominent.*

Picea excelsa, Link. Spruce (Fig. 123). Tall Fir, with pseudo-whorled branches, and distichous twigs, sweeping downwards and forwards. Leaves spirally disposed, solitary but crowded, persisting 5—7 years, twisted forwards, especially above, and with a slight tendency to pseudo-distichy in 2—3 ranks below; leaf-base narrowed to a short petiole, inserted on a prominent angular cushion. Tetragonal, shining green, with very fine stomatal lines on all surfaces; rough, acute or mucronate and even pungent, about 1—3 cm. × 1 mm. Palisade layer not distinct above and below. Venation simple. Vascular bundle undivided. Dying leaves yellow.

‡‡ *Leaves flat, with two silvery stomatal lines beneath. Leaf-base not prominent.*

Pseudotsuga Douglasii. Douglas Fir (Fig. 124). Tall Fir with characters intermediate between the Spruces and Silver Firs, with leaves more pointed and falcate

upwards, less pseudo-distichous, and with fainter stomatal lines than in *Abies.* Persisting 6—7 years, equal, twisted into 3—4 ranks, narrow-linear, flat, 2—4 cm. × 1·5 mm., obtuse or mucronate, bright shining green with an obscure median line above, paler with two silvery stomatal bands

Fig. 123. Spruce, *Picea excelsa*, p. 316 (Wi).

beneath. Stomata beneath only Leaf almost elliptic-oblong in section, with a resin-duct at each margin below. Vascular bundle undivided. Best distinguished by its cones. Dying leaves yellow. Venation simple.

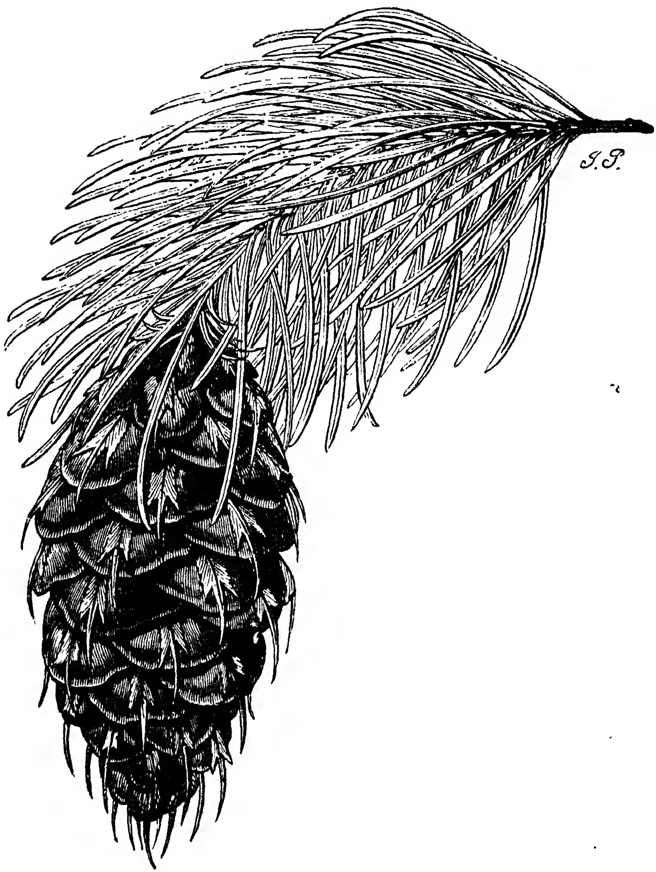

Fig. 124. *Pseudotsuga Douglasii*, showing the pendent cone, and exserted three-pronged barren scales, p. 316 (V).

BIBLIOGRAPHY.

In addition to Authorities quoted in Volume I., the student may consult the following.

BLACKMAN, F. F., *Experimental Researches on Vegetable Assimilation and Respiration*, I. and II., Phil. Trans., 1895.

BROWN, H., AND ESCOMBE, *Static diffusion of Gases and Liquids in relation to the Assimilation of Carbon*, &c., Phil. Trans., Vol. 193, 1900, p. 223.

CAMUS, A. AND E. G., *Classification des Saules d'Europe*, Paris, 1904.

DARWIN, C., *Climbing Plants*, London, 1875.

DARWIN, C., *The Movements of Plants*, London, 1880.

DARWIN, F., *Observations on Stomata*, Phil. Trans., 1898.

DAYDON JACKSON, *A Glossary of Botanic Terms*, London, 1900.

ETTINGSHAUSEN, *Die Blatt-skelete der Dicotyledonen*, &c., Vienna, 1861.

ETTINGSHAUSEN, *Physiographie der Medicinal-pflanzen*, &c., Vienna, 1862.

HEMPEL AND WILHELM, *Die Bäume und Sträucher des Waldes*, Vienna, 1899.

HÖHNEL, *Centralblatt für das ges. Forstwesen*, Vol. x., Vienna, 1884.

LINDLEY, *Descriptive Botany*, London, 1858.

MASTERS, *A General View of the Genus Pinus*, Linn. Journ. 1904, Vol. XXXV., No. 248.

MATTHAEI, *Experimental Researches on Vegetable Assimilation*, III., Phil. Trans., Vol. 197, 1904.

PAX, *Aceraceæ*, in Engler's *Das Pflanzenreich*, IV. 163, Berlin, 1902.

PFEFFER, *The Physiology of Plants*, Oxford, 1900. Engl. Ed.

PILGER, *Taxaceæ*, in Engler's *Das Pflanzenreich*, IV. 5, Berlin, 1903.

SCHNEIDER, *Handbuch der Laubholzkunde*, Lfg. I. and II., Jena, 1904.

STAHL, *Einige Versuche über Transpiration*, &c., Bot. Zeitung, 1894.

VAN TIEGHEM, *Bull. de la Soc. Bot. de France*, 1886, p. 88.

VINES, *Lectures on the Physiology of Plants*, Cambridge, 1886.

GLOSSARY.

Acicular, needle-shaped, e.g. Pine needles, as in Fig. 6, p. 22.

Acuminate, with a drawn-out, tapering apical point, as in Fig. 10, p. 28.

Acute, distinctly pointed, but not drawn out, at the apex, as in Fig. 10, p. 28.

Adnate, attached along the whole of the side, p. 19.

Adventitious, arising in wrong order or position, p. 216.

Afferent, carrying to or towards, p. 80.

Air-cavity, the large intercellular space into which the stoma opens, p. 101.

Alternate, of leaves inserted singly on nodes at different levels, p. 6.

Amylogenesis, the process of building up starch from the elements of carbon-dioxide and water, p. 135.

Angular divergence, the angle between leaves projected on the same spiral or circle, p. 6.

Anther, that part of the stamen in which the pollen-grains are formed, p. 71.

Antherozoids, male motile sexual organs of certain plants, p. 76.

Apex, the tip of the leaf, shoot, &c., p. 28.

Appressed, closely pressed on to a surface, p. 37.

Arachnoid, like spider's webs.

Arcuate, venation where the secondaries arch forward towards the apex, p. 35.

Arenicolous, growing best in sand.

Assimilation, *see* Photo-synthesis, p. 95.

Attenuate, tapering off.

Auricle, a small ear-like lobe, p. 205.

Axis, the part bearing lateral organs, such as the stem, flower-stalk, &c., p. 7.

Base, the part of the leaf nearest the insertion, p. 23.

Bi-facial, with the upper and lower faces different in construction, p. 146.

Bloom, the peculiar surface so easily rubbed off grapes, plums, &c., due to a thin superficial layer of wax, p. 278.

Caducous, falling very early, much earlier than deciduous, p. 21.

Callous, of a horny appearance.

Cartilaginous, like cartilage, hard and tough, p. 262.

Catkin, a deciduous spike of inconspicuous unisexual flowers.

Cell, a plant-unit composed of a bag-like membrane enclosing living contents; but vaguely used to denote the chamber from which the contents have disappeared, or the protoplasm itself, p. 66.

Cell-cavity, the cavity enclosed by the cell-wall, p. 68.

Cell-chamber, a cell devoid of its living contents, p. 77.

Cell-contents, the total mass contained in a cell, p. 68.

Cell-sap, the liquid contents of the cell, p. 76.

Cell-tissue, a group of cells formed by division, remaining in connection and growing in common, p. 77.

Cellulose, the carbohydrate most commonly forming the basis of the cell-wall.

Cell-wall, the membrane which encloses the contents of the cell, p. 68.

Chlorophyll, the green colouring matter of ordinary leaves, p. 94.

Chlorophyll-corpuscles, the green bodies in the cells, which carry the chlorophyll and in which starch and other carbohydrates are formed, p. 94.

Chlorovaporisation, the emission of water from the chlorophyll-corpuscles.

Cicatrix, a scar after healing over, p. 16.

Ciliate, margin bearded with fine hairs reminding one of the eye-lash, p. 37.

Ciliate-dentate, dentate, with each tooth drawn to a fine ciliate point, p. 37.

Cladode, a branch so flattened as to simulate a leaf, p. 297.

Cleft, divided one from another by intervals which may reach to any depth towards the midrib, p. 40.

Climber, a plant which ascends by using other objects as supports.

Compound, of several nearly isolated parts aggregated into one whole, p. 40.

Conduplicate, folded lengthwise on the midrib so that the two upper half-surfaces are applied as two pages of a book, p. 273.

Connate, grown together so as to look like one whole, p. 17.

Convolute, rolled up so that one half is rolled in the other, p. 270.

Cordate, heart-shaped, with the base cut in like the heart of cards, as in Fig. 7, p. 23.

Coriaceous, leathery, p. 37.

Cortex, the tegumentary tissues covering the wood and bast in branches and stems which have lost the epidermis.

Cotyledon, the first lobe or leaf of a seedling.

Crenate, scalloped with rounded shallow teeth, as in Fig. 9, p. 27.

Cross-ties, tertiaries which run straight across between the secondaries like rungs of a ladder, p. 53.

Cuneate, wedge-shaped, triangular, p. 23.

Cuneiform, *see* Cuneate, p. 23.

Curved-parallel, venation in which the ribs are nearly parallel along most of the curved course, p. 35.

Cuspidate, tipped with a sharp tooth.

Cut, *see* Cleft, p. 40.

Cuticle, the thin impervious layer covering the outer surface of the epidermis, p. 98.

Cytoplasm, the cell-protoplasm, p. 74.

Deciduous, falling as the parts attain full growth, p. 21.

Decussate, in pairs and opposite, but each alternate pair at right angles, p. 7.

Deltoid, shaped like the Greek letter Δ, an equilateral triangle, Fig. 7, p. 23.

Dentate, toothed, as in Fig. 9, p. 27.

Dia-geotropic, growing normally across the vertical, p. 110.

Dia-heliotropic, growing normally across the axis of incident rays of light, p. 110.

Dichotomous, forked branching.

Digitate, with about 5—7 leaflets all radiating like fingers from the top of the petiole, p. 43.

Distichous, in two vertical ranks, p. 5.

Efferent, carrying away from, p. 80.

Elliptical, *see* Oval, Fig. 6, p. 22.

Embryonic cell, a cell not yet specialised or differentiated as part of any particular organ or tissue, p. 77.

Endodermis, the innermost layer of the cortex separating the central axis of tissue from the rest, &c., p. 316.

Endosperm, the tissue containing food-material in certain seeds.

Entire, margin not cut in any way, as in Fig. 9, p. 27.

Enzyme, a so-called unorganised or soluble ferment capable of producing important changes in starches, sugars, proteids, &c., breaking them up or altering their molecular structure.

Epidermis, the outer layer of leaves, shoots, &c., p. 81.

Etiolated, pale and drawn and watery from deprivation of light, p. 129.

Exstipulate, devoid of stipules, p. 20.

Falcate, curved like the blade of a reaping hook, p. 316.

Fan-like, venation in which the principal ribs radiate like the spokes of a fan, p. 35.

Fascicled, gathered into bundles or tufts, p. 305.

Fastigiate, with the branches erect and clustered as in a broom, p. 263.

Ferruginous, rusty, as if covered with iron rust.

Filiform, thread-like.

Flaccid, limp, flabby, p. 87.

Fleshy, soft and juicy, p. 37.

Free, not adnate or attached, p. 19.

Furcate, forked into two prongs, p. 35.

Geotropic, responding to directive influence of gravitation during growth, p. 109.

Gimped, *see* Crenate, p. 27.

Glabrescent, becoming almost but not quite glabrous, p. 36.

Glabrous, devoid of hairs, p. 36.

Glandular, studded with or ending in glands, p. 37.

Glaucous, sea-green, normally due to thin waxy deposits, p. 36.

Gourmandiser, a powerfully and coarsely growing sucker.

Growing-point, the true apex of a growing organ where new cells are constructed, p. 73.

Guard-cell, one of the pair of cells comprising the stoma, p. 98.

Gutter-pointed, acuminate with the point channelled above, like a spout.

Hastate, shaped like the blade of a halbert; like sagittate, but the lobes out-turned, p. 23.

Heliotropic, showing response to the directive action of light during growth, p. 109.

Herbaceous, soft and green like ordinary herbs, p. 37.

Heterophylly, where differently shaped leaves co-exist on the shoot.

Hispid, beset with stiff bristly hairs, p. 37.

Histology, minute structure, requiring the microscope for examination, p. 67.

Hybrid, the result of crossing two species.

Imbricate, overlapping at the edges like one tile over another.

Immersed, embedded in.

Impari-pinnate, pinnate with an odd terminal leaflet, p. 44.

Incised, *see* Cleft.

Infra-marginal, just beneath the margin, p. 57.

Insertion, the place where the leaf is attached to the stem, p. 3.

Intercellular spaces, the spaces formed by the partial separation of cells, p. 89.

Internode, the stretch of stem between successive nodes, p. 4.

Involute, both edges rolled in towards the midrib on the upper surface of the leaf, p. 274.

Keeled, with the midrib projecting like the keel of a boat.

Lamina, the blade of the leaf, p. 14.

Lanceolate, with an outline like the head of a lance, tapering to each end, as in Fig. 7, p. 23.

Lateral, arising from the flanks or sides.

Latex, milk-like juice.

Leaf-incept, the earliest recognisable stage of a developing leaf, p. 38.

Leaflet, one of the blades of a compound leaf, p. 40.

Leaf-mosaic, the fitting into a surface of exposed leaves, p. 9.

Lenticel, cork-like spots on twigs and branches which admit air, &c.

Linear, very narrow, with parallel edges, as in Fig. 6, p. 22.

Lobe, one of the parts into which a leaf is cut, when the incisions are too deep and distant for teeth but too shallow for segments; as in Fig. 9, p. 27.

Looped, venation where the secondaries turn at their ends and join on to the next secondaries in loop-like curves, p. 34.

Maculate, spotted or blotched, p. 37.

Margin, the edge of the leaf, p. 27.

Membranous, thin and more or less translucent, p. 37.

Mesophyll, softer green tissue between the ribs and veins of the leaf, p. 86.

Middle lamella, the primary cell-membrane recognisable in the median plane of thickened cell-walls, p. 70.

Midrib, the principal rib running approximately up the central axis of the leaf, p. 48.

Morphology, the study of form and development.

Mucronate, with a short, sudden apical point, as in Fig. 10, p. 28.

Multi-foliolate, with many leaflets, p. 44.

Node, the joint-like swelling where leaves are inserted, p. 4.

Nodose, where the nodes are close and prominent and knot-like.

Nucleus, an important protoplasmic body in the cell, with essential functions in cell-division, reproduction, &c., p. 74.

Nucleolus, a small mass of protoplasm recognisable in the nucleus, p. 74.

Nutation, a nodding movement described by the apex of rapidly growing shoots, p. 114.

Nyctitropic, the night-position observed in many leaves, &c., p. 112.

Obcordate, cordate, but reversed, the narrow end next the leaf-insertion, as in Fig. 8, p. 23.

Oblong, like an ellipse flattened so that the sides are parallel for some distance, as in Fig. 6, p. 22.

Obovate, ovate, but reversed, the narrower end next the leaf-insertion, as in Fig. 8, p. 23.

Obscure, venation when the venation is very slight, little or no more than a midrib being discernible, p. 55.

Obtuse, bluntly rounded at the apex, as in Fig. 10, p. 28.

Ochrea, sheath formed by conjoined stipules round the shoot, p. 20.

Octostichous, in eight orthostichies or vertical ranks, p. 6.

Oosphere, the egg-cell; the primordial cell which after fertilization will become an embryo, p. 77.

Opposite, leaves in pairs at each node and inserted on opposite sides, p. 7.

Organography, the description of the organs of the plant.

Orthostichy, a vertical rank of leaves, &c., p. 7.

Osmotic, having a powerful attraction for water and capacity for holding it under certain conditions.

Oval, in the shape of an ellipse, as in Fig. 6, p. 22.
Ovate, with an outline like that of an egg, the broader end next the leaf-insertion, as in Fig. 7, p. 23.
Palæontology, the study of plants and animals in a fossil state, p. 36.
Palisade tissue, the close-celled tissue of the upper mesophyll, p. 88.
Palmate, with lobes or ribs radiating like the fingers of the open hand, pp. 34, 40.
Palmate-pinnate, the primary ribs arranged in palmate order, giving off secondaries in pinnate order, p. 35.
Palmate-reticulate, the primary ribs arranged in palmate order, the secondaries rapidly forming a meshwork, p. 65.
Palmatifid, leaf-blade cut about half-way in, in palmate manner, p. 40.
Palmatisect, cut deeply into lobes in palmate manner, p. 40.
Parallel-veined, with the principal ribs running side by side for some distance, p. 33.
Parasite, a plant which derives some or all of its food from another living organism.
Pari-pinnate, pinnate with equal pairs and no odd lobe, p. 44.
Peltate, shield-shaped with the stalk in the middle of the lower surface, p. 37.
Pentastichous, in five vertical orthostichies or ranks, p. 6.
Periderm, the corky layers of the cortex.
Petiolate, having a leaf-stalk, p. 17.
Petiole, the leaf-stalk, p. 17.
Petiolule, the stalk of a leaflet in a compound leaf, p. 42.
Photo-synthesis, the building up of carbohydrates from carbon-dioxide and water under the influence of light, p. 95.
Phylloclade, a branch so flattened, &c. as to resemble a leaf.
Phyllode, a petiole flattened so as to resemble and behave like a leaf.
Phyllotaxy, leaf-arrangement on the shoot, p. 4.
Physiology, the study of the functions performed by living organs.
Pilose, softly hairy, with rather long hairs, p. 37.
Pinnate, with leaflets arranged along the opposite sides of the common petiole, p. 40.
Pinnate-arcuate, venation in which the secondary veins curve forwards towards the apex and there end, p. 58.
Pinnate-looped, venation with the secondaries arranged in pinnate fashion and looping forwards on to the next secondary, p. 58.
Pinnate-reticulate, venation pinnate, but the secondaries rapidly breaking up at their ends into a meshwork, p. 59.
Pinnatifid, leaf-blade cut about half-way in, in pinnate fashion, p. 40.
Pinnatisect, cut deeply into lobes in pinnate manner, p. 40.
Plastidia, *see* Plastids, p. 74.
Plastids, minute corpuscles in the protoplasm, p. 74.

Plicate, folded on the principal ribs as a fan is folded.

Polished, shining as if polished, p. 36.

Pollard, a tree repeatedly pruned by lopping close to the junction of the stem and the crown.

Pollen-grain, the dust-like powder discharged from the anther to be deposited on the stigma, p. 71.

Primordial cell, a living mass of protoplasm which has not yet formed its cell-membrane, p. 77.

Prominent, standing off from the general surface, p. 36.

Prostrate, lying flat on the ground.

Protoplasm, the viscous living substance of the cell, alone capable of assimilating new materials and converting them into new plant-substance, p. 74.

Pseudo-palmate, falsely palmate: the primaries diverging from the leaf-base, but not exactly from the same point, p. 63.

Pseudo-parallel, like curved-parallel, but with a distinct network between the principal ribs, p. 35.

Puberulent, faintly pubescent.

Pubescent, softly hairy, downy, p. 36.

Pulverulent, looking as if covered with dust.

Pulvinule, the small pulvinus of a leaflet, p. 43.

Pulvinus, the cushion-like swelling at the base of some petioles, p. 42.

Pungent, ending in a sharp pricking point, p. 191.

Quincuncial, of five leaves, &c., so arranged that two are wholly outside, two inside, and one with one margin exterior, and the other interior.

Quinque-foliolate, with five leaflets, p. 43.

Rachis, the common leaf-stalk on which the leaflets of a compound leaf are arranged, p. 40.

Radical, appearing as if springing from the root in the soil, p. 4.

Raphides, needle-shaped crystals of calcium-oxalate found in some cells.

Reniform, kidney-shaped, as in Fig. 7, p. 23.

Respiration, the taking in of oxygen and giving off of carbon-dioxide common to all living parts of higher plants and animals, p. 125.

Reticulated, netted, as in ordinary venation, p. 33.

Retuse, notched at the apex, as in Fig. 10, p. 28.

Rib, one of the stronger strands of vascular bundles in the leaf, p. 32.

Rosulate, in little rosettes, p. 4.

Rotund, rounded, approximately circular, p. 22.

Rugose, wrinkled, p. 36.

Sagittate, shaped like an arrow-head, as in Fig. 7, p. 23.

Scabrid, rough like a file, p. 37.

Scarious, brown, as if toasted or scorched.

Scattered, inserted singly at various intervals, or without obvious order, p. 4.

Sclerenchyma, tissue of cells with hard cell-walls like those in the stone of a plum, &c.

Scrambler, a plant which flings itself loosely over other objects.

Secondary ribs, the ribs given off directly from the midrib or primaries, p. 48.

Serrate, toothed like a saw, as in Fig. 9, p. 27.

Sessile, seated directly on the stem, &c., without the intervention of a petiole or other stalk, p. 17.

Setaceous, bristle-like, p. 172.

Sheath, the dilated lower end of the petiole enveloping the shoot, p. 19.

Sheathing, forming a sheath, p. 19.

Silky, like pubescent, but the hairs appressed to the surface and glistening like silk, p. 36.

Simple, of one piece, as a leaf of one lamina only, p. 15.

Simple, venation when the midrib alone is visible, p. 55.

Sinuate, wavy at the margin, as in Fig. 9, p. 27.

Sinus, the interval between two lobes, p. 40.

Spathulate, shaped like a spatula, as in Fig. 8, p. 23.

Spinose, studded with or ending in spines, p. 37.

Spongy tissue, the loose-celled part of the mesophyll, p. 86.

Spore, a special cell set free and capable of growing into a new individual, p. 71.

Stellate, star-shaped, p. 37.

Stipules, small paired appendages at the base of the petiole of many leaves, p. 19.

Stoma, an aperture in the epidermis through which the gases in and outside the leaf communicate, p. 98.

Straight-parallel, venation in which the principal ribs run straight and parallel almost the whole way, p. 35.

Striate, marked with fine lines.

Strict-pinnate, venation where the secondaries run stiff and straight from midrib to margin, p. 55.

Sub-rotund, nearly circular, as in Fig. 6, p. 22.

Subsidiary cell, a cell abutting on the guard-cell of a stoma, p. 102.

Subulate, shaped like a shoemaker's awl or other stiff tapering tool, as in Fig. 7, p. 23.

Sucker, an organ by means of which a plant attaches itself to another and absorbs food-materials from it.

Suppression, keeping back, or in the background.

Teleology, the doctrine which ascribes definite causes or aims to an organ or being, p. 146.

Terete, cylindroid, but tapering somewhat upwards.

Terminals, the ultimate branches of the venation, p. 48.

Tertiary ribs, the small ribs coming off from the secondaries in the venation, p. 53.

Tissue, any aggregate of cells or vessels, &c., which follow common laws of growth and development, p. 69.

Tomentose, woolly with long soft matted hairs, p. 37.

Transpiration, the giving off of water-vapour from the surface of a leaf, p. 122.

Tri-foliolate, compound leaf with three leaflets, p. 44.

Trigonal, triangular in section.

Tripartite, deeply divided into three lobes or segments, p. 40.

Triquetal, *see* Trigonal.

Tristichous, in three vertical ranks or orthostichies, p. 5.

Truncate, sharply cut off at the apex.

Tuber, a short, thickened, underground reservoir of reserve-materials, e.g. Potato or Dahlia tuber, p. 66.

Tuberculate, in the form of little swellings.

Turgid, tense and swollen under the pressure of the cell-sap, p. 87.

Typical, fairly representative of the kind of thing referred to, p. 3.

Uni-foliolate, a compound leaf which has but one leaflet, p. 44.

Vacuole, a cavity in the protoplasm full of sap, p. 75.

Variegated, irregularly marked with patches of different colour, p. 37.

Varnished, the cuticle covered with a glistening film, p. 36.

Vascular bundles, the strands of special tissues, vessels, &c., which conduct water and other liquids, p. 83.

Vascular system, the system of strands composed of vessels, &c., in the venation of the leaf, and in the wood and bast of the shoot and root, p. 83.

Vein, one of the smaller strands of vascular tissue in a leaf, p. 32.

Venation, the branched system of strands of vascular bundles in the leaf, p. 32.

Verticillate, whorled, p. 7.

Vessels, tubes formed by the junction of superposed rows of cells, the contents of which may vary considerably, p. 78.

Villous, velvety to nearly shaggy, with erect soft hairs.

Water-pore, a large stoma which exudes water under pressure, p. 105.

Water-stoma, a water-pore, p. 105.

Whorled, leaves or other organs inserted at the same level round the axis, p. 7.

Winged, with a membranous margin, p. 18.

Zoospore, a motile spore or cell of one of the lower Cryptogams (Algæ, Fungi, &c.), living in water, p. 77.

INDEX.

CAMBRIDGE: PRINTED BY J. AND C. F. CLAY, AT THE UNIVERSITY PRESS.

CAMBRIDGE BIOLOGICAL SERIES.

General Editor, A. E. SHIPLEY, M.A., F.R.S., Fellow and Tutor of Christ's College.

A Text-Book of Zoogeography. By FRANK E. BEDDARD, M.A., F.R.S., Prosector of the Zoological Society of London. With 5 Maps. Crown 8vo. 6*s*.

The Elements of Botany. By FRANCIS DARWIN, M.A., M.B., F.R.S., Fellow of Christ's College. With 94 Illustrations. Crown 8vo. *Second Edition.* 4*s*. 6*d*.

Journal of Education. A noteworthy addition to our botanical literature.

Practical Physiology of Plants. By FRANCIS DARWIN, M.A., F.R.S., and E. HAMILTON ACTON, M.A. Crown 8vo. With 45 Illustrations. *Second Edition.* 4*s*. 6*d*.

Nature. The authors are much to be congratulated on their work, which fills a serious gap in the botanical literature of this country.

Morphology and Anthropology. By W. L. H. DUCKWORTH, M.A., M.D., Fellow and Lecturer of Jesus College, University Lecturer in Physical Anthropology. Demy 8vo. 15*s*. *net*.

Daily News. A timely and valuable contribution to the comparative study of man as an animal, for it not only contains the conclusions of previous investigators, but Mr Duckworth has introduced a very large amount of original work, and has copiously illustrated it with clear, bold sketches.

Lectures on the History of Physiology during the Sixteenth, Seventeenth and Eighteenth Centuries. By Sir M. FOSTER, K.C.B., M.P., M.D., D.C.L., F.R.S., Fellow of Trinity College. Demy 8vo. With a Frontispiece. 9*s*.

Nature. There is no more fascinating chapter in the history of science than that which deals with physiology, but a concise and at the same time compendious account of the early history of the subject has never before been presented to the English reader. Physiologists therefore owe a debt of gratitude to Sir Michael Foster for supplying a want which was widely felt....No higher praise can be given to the book than to say that it is worthy of the reputation of its author....It is by no means an easy task to do adequate justice to the mine of literary and historic research which the author has laid open to view.

The Soluble Ferments and Fermentation. By J. REYNOLDS GREEN, Sc.D., F.R.S., Professor of Botany to the Pharmaceutical Society of Great Britain. *Second Edition.* Demy 8vo. 12*s*.

Nature. It is not necessary to recommend the perusal of the book to all interested in the subject since it is indispensable to them, and we will merely conclude by congratulating the Cambridge University Press on having added to their admirable series of Natural Science Manuals an eminently successful work on so important and difficult a theme, and the author on having written a treatise cleverly conceived, industriously and ably worked out, and on the whole, well written.

Cambridge Biological Series.

The Natural History of some Common Animals. By OSWALD H. LATTER, M.A., Senior Science Master at Charterhouse. Crown 8vo. 5*s.* *net.*

Journal of Education. We are very favourably impressed by Mr Latter's book, and the author is to be congratulated on having produced an excellent work....Much praise is due to the illustrations and to the careful way in which the lettering has been done. We can confidently recommend the book to teachers of science.

Nature. An excellent book, written by a man who is equally in his element whether he writes as an outdoor naturalist or as a laboratory student. This combination is by no means a common one, and it is just the combination that is wanted for a book of this kind....Altogether the book is an admirable one.

Athenæum. A book that may be judiciously placed in the hands of any boy who evinces a reasonable interest in the animal life around him.

The Classification of Flowering Plants. By ALFRED BARTON RENDLE, M.A. (Cantab.), D.Sc. (Lond.), F.L.S., Assistant in the Department of Botany, British Museum. Vol. I. Gymnosperms and Monocotyledons. Demy 8vo. With numerous illustrations. 10*s.* 6*d.* *net.*

Pall Mall Gazette. The information throughout is clearly the outcome of deep thought, keen observation, and years of original study. Dr Rendle has the happy knack of hitting upon, and discussing with exactitude and clearness, the very difficulties which beset the thoughtful student, as though he himself were constantly confronted by the ever recurring "Why" of the anxious learner.

Gardener's Chronicle. Numerous illustrations and an excellent index add to the value of the work. We heartily congratulate the author on the partial accomplishment of a difficult and laborious task. The part before us does but whet our appetite for what is to follow.

Athenæum. The first instalment of a text book which will well represent the state of our knowledge in the early years of the century. In the present volume the Gymnosperms and the Monocotyledons alone are dealt with; but they are treated with such excellent co-ordination of detail and such clear-headed sense of proportion, that we eagerly await the publication of the next instalment.

The Vertebrate Skeleton. By SIDNEY H. REYNOLDS, M.A. Crown 8vo. With 110 Illustrations. 12*s.* 6*d.*

The Origin and Influence of the Thorough-bred Horse. By W. RIDGEWAY, M.A., F.B.A., Disney Professor of Archæology and Fellow of Gonville and Caius College. With numerous Illustrations. Demy 8vo. 12*s.* 6*d.* *net.*

Westminster Gazette. There has never been a more learned contribution to equine literature than Professor Ridgeway's comprehensive and exhaustive book.

Scotsman. He has brought together such an enormous mass of evidence that an attempt to confute him would be an arduous task.

Cambridge Biological Series.

Manual of Practical Morbid Anatomy, being a Handbook for the Post-mortem Room. By H. D. ROLLESTON, M.A., M.D., F.R.C.P., and A. A. KANTHACK, M.D., M.R.C.P. Crown 8vo. 6*s*.

Fossil Plants: for students of Botany and Geology. By A. C. SEWARD, M.A., F.R.S., Fellow of Emmanuel College. In 2 vols. Demy 8vo. Vol. I. 12*s*. [Vol. II. *In the Press.*

Revue Scientifique. Nous ne pouvons entrer dans le détail; mais il est évident que M. Seward, praticien distingué lui-même, est très au courant des travaux des autres, il les cite et utilise abondamment; et ceci est fait pour inspirer confiance. Au total, son œuvre est appuyée sur des bases solides, et elle restera sans doute longtemps le bréviaire, le manuel de ceux qui veulent, non pas seulement s'initier à la paléobotanique, mais retrouver les renseignements qui sont épars dans des centaines de monographies qu'on a souvent peine à se procurer. Le livre de M. Seward fait partie des *Cambridge Natural Science Manuals*, et il est digne de cette collection, qui est elle-même digne du foyer scientifique universellement réputé, où il a vu le jour.

Zoology. An Elementary Text-Book. By A. E. SHIPLEY, M.A., F.R.S., and E. W. MACBRIDE, M.A. (Cantab.), D.Sc. (London), Professor of Zoology in McGill University, Montreal. Demy 8vo. With numerous Illustrations. 10*s*. 6*d*. *Net.*

Pall Mall Gazette. Precisely the sort of book which, if it came into a thoughtful boy's hands, would turn him from a smatterer into a student.... One of the most instructive and attractive books that could be put into the hands of a young naturalist.

Trees: A Handbook of Forest Botany for the Woodlands and the Laboratory. By H. MARSHALL WARD, Sc.D., F.R.S., Fellow of Sidney Sussex College, Honorary Fellow of Christ's College and Professor of Botany in the University of Cambridge. In six volumes. 1. Buds and Twigs, 2. Leaves, 3. Inflorescences and Flowers, 4. Fruits and Seeds, 5. Seedlings, 6. General Characters. Vols. I., II. & III. *now ready.* Crown 8vo. Illustrated. 4*s*. 6*d*. *net each.*

Nature. The clear and simple way in which the author treats the subject is sure to inspire many with interest and enthusiasm for the study of forest botany....The work will be found indispensable to those students who wish to make an expert study of forest botany. At the same time it is expressed in language so clear and devoid of technicalities that the amateur who wishes to know something about our trees and shrubs will find this one of the most useful guides to which he can turn....The work is a many sided one, acting not only as a guide to the naturalist in the field, but also as a laboratory handbook, where the use of the lens and microscope may be employed to amplify the study of objects already observed in their natural habitats. Botanists generally, and especially forest botanists will welcome the appearance of this book as supplying a decided want, and filling a distinct gap in our literature of forest botany.